CLIMATE CHANGE
ADAPTATION PROGRAM

Maintaining and Enhancing Agricultural Dams in the Cariboo Region

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Maintaining and Enhancing Agricultural Dams in the Cariboo Region

Discussion Document

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Report prepared by:

nhc
northwest hydraulic consultants
water resource specialists

Cariboo Agricultural Adaptation Project Management Committee:
Samantha Charlton
Allen Dobb
Jenny Huffman
Geneve Jasper
Emily MacNair
Katharine VanSpall

Cariboo Agricultural Adaptation Working Group:
Duncan Barnett
Rob Borsato
Jenny Huffman
Geneve Jasper
Karen Moores
Tom Salley
Joan Sorley

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The following NHC personnel participated in developing draft content and background research for this report:

Dale Muir, Principal (Project Manager)

Northwest Hydraulic Consultants

dmuir@nhcweb.com

Jeremy Cooke, Senior. Engineer

Northwest Hydraulic Consultants

jcooke@nhcweb.com

Meg Broswick, Project Engineer

Northwest Hydraulic Consultants

mbroswick@nhcweb.com

Dr. Mariza Costa-Cabral, Senior Scientist

Northwest Hydraulic Consultants

mcabral@nhcweb.com

Joe Drechsler, GIS Lead

Northwest Hydraulic Consultants

jdrechsler@nhcweb.com

EXECUTIVE SUMMARY

Project background and objectives

In the Cariboo region, agricultural dams play a significant role in retaining water for agriculture during the production season. With the effects of climate change on hydrology and temperatures, ensuring sustainable water supply for agriculture will become increasingly critical in the future. However, in recent years challenges have emerged related to maintaining accessible, reliable water sources and meeting dam safety requirements under the *B.C. Dam Safety Regulation*.

The underlying goal of this project is to help to ensure the availability of sustainable and adequate water supply for future agricultural production in the Cariboo region. In the interests of supporting this goal, the project objectives are to:

1) Improve the knowledge of the existing agricultural dams, with regards to their status, condition and associated issues;
2) Identify potential cost and risk-sharing models for inspections, upgrades, and maintenance of agricultural dams;
3) Outline collaboration and partnership opportunities to address the requirements for dam safety and sustainable agricultural water supply; and
4) Identify, describe, and document the co-benefits associated with maintaining and enhancing agricultural dams.

While the issues with agricultural dams and their safety are pressing, it was not the purpose of this report to provide direction or to be definitive in terms of the issues, options and next steps. The report is intended to support a constructive dialogue amongst dam owners, relevant agencies and potential partners about how best to address the issues and challenges related to agricultural dams. It is hoped that the report will support the necessary near-term actions, starting with a workshop to bring together Cariboo dam owners, related agencies and partners on November 25, 2015.

Project scope

The scope of work for this project included an inventory of agricultural dams within the region and consultation with local stakeholders (i.e. local producers, provincial government agencies, and Ducks Unlimited Canada) to assess the magnitude and nature of issues and challenges. Also included is an analysis of how climate change will impact agricultural dams and a summary of the various costs associated with the regulatory requirements for dam owners. In addition, potential solutions for the identified challenges are explored, along with options for sharing risks and costs associated with agricultural dams.

The project scope did not include detailed assessment or inspection of individual agricultural dams. Project scope also didn't involve evaluation of the physical infrastructure or technical issues with individual dams. Therefore, the study does not provide solutions that are specific to individual dam owners and instead focuses on shared issues and concerns. The scope did not include evaluation of the provincial *B.C. Dam Safety Regulation* or the B.C. Dam Safety Program.

Climate change & agricultural dams

Some of the anticipated impacts of climate change to the Cariboo region's agricultural dams are summarized below. More details may be found in the full report.

- Higher temperatures and longer dry periods during summer are likely to decrease water supply and increase the need for water storage and yield capacity of agricultural dams.
- Higher temperatures and less frequent precipitation are anticipated to increase the risk of wildfire events. Wildfires can have long-term impacts on soil, vegetation and runoff hydrology in watersheds and fire-fighting could compete for water supplies.
- The timing and volume of peak runoff flows may have negative impacts on agricultural water storage, as the early season flows may not coincide with the growing season.
- Earlier and greater freshet flow is expected to result in increased flooding, erosion, debris supply, and channel changes.
- Greater freshet flows could lead to increased flow requirements for spillway capacity and dike crest elevation.
- Increased variability and changes in timing of streamflow may make operation of dams more difficult. This is most likely to occur where dam operation is integrating multiple objectives such as flood control, habitat (water fowl, fish, amphibians), recreation, irrigation and/or livestock water.

Requirements of dam ownership in B.C.

The full report includes a high level summary of dam safety regulations in B.C. including the definition of a dam, the requirements of a Dam Safety Management System and the frequency of associated activities. A series of tables outline the range of potential costs associated with the following aspects of dam ownership:

- Cost estimates for the operation and maintenance typical earthfill dams with different consequence ratings
- Costs of additional studies and investigations potentially required during detailed Dam Safety Review for High and Very High consequence classified dams
- Costs for upgrades based on generic deficiencies potentially identified through a DSR, dam audit, or routine surveillance and maintenance

Inventory Summary

The inventory includes 403 dams. Of these, the majority, or 60%, have a low consequence classification. Another 20% have a significant classification, and 8% have high classification, while two dams (.5%) have a very high classification. The remainder are either undetermined (6%) – indicating that it's likely that the dam does not meet the definition covered of a dam under the current regulation – or unknown (5%), meaning that consequence information is not available.

Priority issues & potential solutions

Agricultural dams in the Cariboo region are diverse with respect to location, age, condition, consequence classification and available water yield. Although each dam is unique, through the inventory, consultation and background research, a series of common issues emerged; primarily pertaining to meeting the requirements of the B.C. Dam Safety Program or to water yield. The priority issues and potential solutions have been divided into the following four categories: 1) Dam Safety Management System, 2) Dam Operation, Maintenance & Surveillance, 3) Dam Safety Reviews; and 4) Water storage

The tables that follow summarize the more detailed descriptions of priority issues and solutions provided in the full report.

Table 1: Summary of Issues and Potential Solutions

Priority #1: Dam Safety Management System	
Issues	**Solutions**
Knowledge and Information Transfer:	
➢ Some owners not aware of their responsibilities as dam owners ➢ Some owners do not have an overarching dam safety management systems in place	• Provide training workshops regarding DSMS and regulations. • Provide owners with the information needed to develop their own system or contacts for individuals or companies who can provide this service.
➢ Some owners have limited knowledge of the Canadian Dam Association guidelines and BC Regulations	• Prepare a user-friendly version of the regulations for dam owners; provide necessary documentation in a form that doesn't require internet access.
MFLNRO Role:	
➢ MFLNRO is taking on more of an enforcement role	• Implement mechanisms to improve communication with dam owners.
➢ Inconsistencies in database and consequence classifications	• Review consequence classifications to ensure that the specified classification is reflective of the site. • Seek continual improvement in the data quality in the public database for better management of sites.
Costs associated with dam assessment, maintenance & upgrades:	
➢ Dam owners may be struggling to cover costs of maintenance/upgrades and this could result in dams being decommissioned	• Explore options for collaboration between dam owners. • Seek opportunities to partner with other dam owners and/or co-beneficiaries of dams including wildlife/recreational users.

Priority #2: Operation, Maintenance & Surveillance	
Issues	**Solutions**
OMS Manual Preparation and Implementation:	
➢ Dam owners not familiar with requirements.	• Deliver OMS training workshops.
➢ OMS manual difficult to comply with or follow; requirements of OMS may not always be feasible or achievable for all sites.	• Ensure OMS manuals are developed with realistic expectations for individual sites.
➢ Requirements for OMS dependent on consequence classification.	• Improve communication between Dam Safety Officer and dam owners to help understand dam classification.
Priority #2: Operation, Maintenance & Surveillance …continued	

Table 1: Summary of Issues and Potential Solutions

Issues	Solutions
Remote Sites:	
➢ Difficult access, especially during winter months (weekly or monthly surveillance required for some dams)	• Incorporate (into OMS manuals) consideration of site access including options for few inspections when water levels are low.
➢ Slow response times to emergencies making it difficult to meet requirements of EPP.	• Upgrade access routes to enable swift response to emergencies or allow for a helicopter use.
➢ Remoteness results in challenges in controlling dam site security and public safety.	• Install public safety warning signs and upgrades to the outlet works to prevent vandalism.
➢ **Condition of Structures and Appurtenances:**	
➢ Older/aging dam structure ➢ Deteriorating outlet structure ➢ Insufficient spillway capacity	• For high consequence dams, complete recommendations from DSR. For low and significant dams continue to maintain and repair structure, as required. • For high consequence dams, complete recommendations from DSR. For low and significant dams, keep spillway clear of debris and install log boom.
➢ Costs of upgrades/repairs	• Explore and implement collaborative/partnership opportunities.

Priority #3: Dam Safety Review

Issues	Solutions
Finding a Qualified Professional (QPEs):	
➢ MFLNRO is no longer providing feedback or guidance on DSRs - therefore QPEs must have the experience to complete a DSR independently.	• More assistance is required from Dam Safety Officers (working with consultants and owners) to ensure acceptable DSRs and to move processes forward.
➢ Liability and limited financial payback are disincentives to QPEs to being involved in conducting DSRs.	• Limit liability either time (duration of liability with respect to study) and/or dollar value (relation to fees). • Seek mechanisms to top-up fees for qualified professionals.
DSR Costs	
➢ Current requirements for engineers to state a dam is safe require extensive background information. ➢ There is insufficient resourcing available to complete the studies and upgrades needed to classify a dam as safe.	• Undertake DSRs with phased approach to collecting additional studies and implementing improvements over time. • Seek/create alternative funding opportunities to pay for DSRs.

Table 1: Summary of Issues and Potential Solutions

DSR Costs …continued	
➢ The requirements outlined in the APEGBC Guidelines and the Regulations require a comprehensive review of all design, construction, performance and safety management arrangements.	• MFLNRO should make more information available about how DSRs are reviewed to aid consultants and owners in efficiently completing DSRs.
➢ Not all agricultural dam owners have the necessary records to complete DSRs, leading to more detailed, costly reviews.	• Local training and support for dam OMS and documentation
Completing necessary upgrades:	
➢ Older dams may require upgrades to meet hydrological and seismic requirements, low level outlets or head gate structures may also require repair. ➢ High risk dams in the Cariboo may not meet the requirements of the Regulations due to age.	• Seek out cost sharing models to help fund necessary upgrades.

Priority #4: Water Storage

Issues	Solutions
Water yield & level limitations:	
➢ Water yields are currently a concern for some agricultural dams	• Maintain water licences and look for opportunities to supplement existing reservoirs with additional water availability; i.e. upstream water licences, multiple smaller storage dams/ponds within one system. • Identify options to create additional water storage
➢ Water level constraints associated with other use requirements (e.g. wildlife and recreation)	• Identify common or complementary objectives with other user groups with regards to water levels (e.g. establishing minimum draw down levels, optimizing water use while reservoir is high).
Changing water demand:	
➢ Increasing agricultural demand due to hotter/drier conditions ➢ Inefficient water management practices	• Explore options for managing agricultural demand • Upgrade irrigation systems to minimize water loss and improve irrigation efficiency
➢ Increasing and/or unpredictable water demand for firefighting - fire risk is anticipated to increase with climate change	• Establish emergency water use plans.
Changing watersheds:	
➢ Changes to upstream watersheds from logging, beetle kill and agricultural activities.	• Implement local watershed planning with all applicable stakeholders (industry, residential, agriculture). Find ways of minimizing the transfer of sub-surface water to surface water.
➢ Early season freshets can result in peak flows outside of agriculture production windows	• Provide more natural storage within the upper reaches of the watershed (e.g. beaver dam development in suitable areas).

Table 2: Priority Solutions and Near-term Actions

Solution Category: Knowledge transfer and informational resources
Near-term Actions
Review previous workshop and training materials and update/refine as needed to support dam owners with addressing current regulatory requirements.
Offer in-person (workshop) training with distinct training/knowledge transfer materials for low and significant consequence, focused on owner responsibilities and maintenance and operational approaches for small earthfill dams.
Offer in-person (workshop) training with distinct training/knowledge transfer materials for high consequence dam owners (including DSR):
Provide a summary (written) of the regulatory requirements (and steps involved in OMS, DSRs etc.). Ensure these documents can be reviewed off line.
Provide periodic refresher or supplemental educational/knowledge transfer opportunities (annually/ near term)
Solution Category: Improved communication with regulator
Near-term Actions
Develop a collaborative approach to delivery of knowledge transfer resources (e.g. workshops/written materials) regarding the dam regulations, OM&S and DSRs
Increase the effective information flow between MFLNRO and dam owners, specifically including:
- Inclusion of dam owners in government audits of dams
- Provision of clear documentation for dam owners and QEPs that details how DSRs are reviewed (to aid in efficiently completing DSRs)
- Provision of clear feedback to dam owners and QEPs about issues with DSRs
Solution Category: Finding qualified professionals
Near-term Actions
Review the list of QEPs produced by the Professional Engineers and Geoscientists of BC and ensure it is comprehensive (e.g. all engineers qualified to do DSRs on earthen dams are included).
Increase awareness and distribution/availability of QEPs list
Develop an option for dam owners to receive a top-up/cost-share on dam assessments (through a cooperative approach or assistance through an external cost-share) to assist in incentivizing engineers who may be deterred by relatively high liability/low compensation currently involved in undertaking DSRs.
Support dam owners to group together by geography and/or shared consequence rating to enable QEPs to undertake a number of DSRs at the same time (i.e. optimize time of professionals from outside the region, seek “economies of scale” by undertaking reviews as a group)

Table 2: Priority Solutions and Near-term Actions

Solution Category: Approaches for sharing risks & costs
a) Collaboration between multiple dam owners
Near-term Actions
Multi-user models: Wildlife, habitat and fisheries values and partners
Conduct an assessment of the types of habitats & species supported by agricultural dams including endangered species, species at risk and recreational fish habitat
Undertake evaluations of individual dams to determine their specific habitat and/or wildlife values (for owners interested in fostering wildlife/habitat values)
Facilitate dialogue between interested dam owners and agencies and opportunities for supportive of wildlife and habitat benefits
Recreation, tourism and/or residential values and models (e.g. downstream development tax)
Investigate appropriate tax tools available to local government & similar application in other BC communities including consideration of implications for implementation
Undertake detailed case study analyses to test assumptions, levels of interest and requirements for implementation
b) Granting & cost-sharing programs
Solution Category: Redeveloping decommissioned dams
Near-term Actions
Undertake a more detailed study of the decommissioned and breached dams to identify those that are of highest priority for future development – include water storage potential, local area water demand, benefits to other resources and high level estimates of upgrade costs in analysis
Solution Category: Managing agricultural water demand
Near-term Actions
Conduct outreach regarding availability of irrigation management planning and cost-shares on irrigation infrastructure improvement through EFP Program
Continue to initiate and support local research and knowledge transfer for improved resilience to drier conditions (e.g. MIG research, forage variety trials etc.)
Solution Category: Watershed planning & natural water storage enhancement
Near-term Actions
Identify areas in need of near-term watershed planning support
Identify key partners with shared interest in undertaking a planning process

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1 INTRODUCTION

Project background & rationale

In 2013-2014, with support from *Growing Forward 2,* the BC Agriculture & Food Climate Action Initiative partnered with local organizations and agencies to develop an adaptation plan for agriculture in the Cariboo region (BC Agriculture & Food Climate Action Initiative, 2014). The resulting *Cariboo Adaptation Strategies* plan identifies the potential impacts of climate change, and strategies and actions for agriculture to adapt. The effects of climate change on local water supply – and the need for sufficient water for livestock and other agricultural production – was a high priority for participating producers.

Within the Cariboo context, agricultural dams play a significant role in retaining water for agriculture during the summer – increasingly critical as hot and dry periods become more extended. Many of the hundreds of dams in the Cariboo region are used for agricultural water. However, in recent years challenges have emerged related to maintaining accessible, reliable water sources and meeting dam safety requirements under the *B.C. Dam Safety Regulation*. As a result, the *Cariboo Adaptation Strategies* includes actions to “inventory and prioritize existing dams and water storage” and to “develop cooperative approaches to dam assessments, upgrades , maintenance and management.” This project - *Cariboo Region Cooperative Maintenance and Enhancement of Agricultural Dams* - evolved in order to implement these actions and move toward achieving the broader strategy (2.1) to “maintain and enhance agriculturally significant dams.”

While the issues with agricultural dams and their safety are pressing, it was not the purpose of this report to provide direction or to be definitive in terms of the issues, options and next steps. The report is intended to support a constructive dialogue amongst dam owners, relevant agencies and potential partners about how best to address the issues and challenges related to agricultural dams. Although the issues and solutions identified in the sections below emerged during consultation and background research, they are not evaluated or prioritized and further validation is required with dam owners, experts and other stakeholders.

It is hoped that this report will support the necessary near-term actions, starting with a workshop to bring together Cariboo dam owners, related agencies and partners on November 25, 2015. While it is unlikely that any single solution will resolve the range of issues identified in this report, the report makes clear that many steps can be taken to improve the current situation and to move towards a resilient and sustainable water supply for agriculture in the Cariboo region.

Project objectives

The underlying goal of this project is to help to ensure the availability of sustainable and adequate water supply for future agricultural production in the Caribooo region. In the interests of supporting this goal, the project objectives are to:

5) Improve the knowledge of the existing agricultural dams, with regards to their status, condition and associated issues;

6) Identify potential cost and risk-sharing models for inspections, upgrades, and maintenance of agricultural dams;
7) Outline collaboration and partnership opportunities to address the requirements for dam safety and sustainable agricultural water supply; and
8) Identify, describe, and document the co-benefits associated with maintaining and enhancing agricultural dams.

Project scope & methodology

Northwest Hydraulic Consultants (NHC) was retained by the Cariboo Cattleman's Association and project partners to complete an assessment of the current state of existing agricultural dams in the Cariboo region.

The scope of work for this project included an inventory of agricultural dams within the region and consultation with local stakeholders (i.e. local producers, provincial government agencies, and Ducks Unlimited Canada) to assess the magnitude and nature of issues and challenges. Also included is an analysis of how climate change will impact agricultural dams and a summary of the various costs associated with the regulatory requirements for dam owners. In addition, potential solutions for the identified challenges are explored, along with options for sharing risks and costs associated with agricultural dams.

In summary, the project scope includes the following elements:

- Climate change impact review
- Agricultural dam inventory
    - Maps, consultation and site visits
- Review of dam regulation requirements and associated costs
- Identification of key issues/solutions

Details regarding the specific tasks undertaken in each of these areas are provided in the sections below.

The geographic scope of the study was defined as the Cariboo Regional District. However, for the purposes of the inventory, agricultural sub-regions were developed based on information provided by the Ministry of Agriculture, Cariboo Cattlemen's Association, and aerial imagery. Aerial imagery was used to delineate agricultural areas. Sub-regions were used to identify dams to include in the study, if other data (such as dam ownership) did not already identify the dam's purpose. Sub-regions are presented in the overall study map (**Map 1, Appendix A**) and summarised below:

- Southern Region
    - 100 Mile/Lac La Hache, Canim Lake, and Horse/Bridge Lake
- Williams Lake Area
    - San Jose Valley, Williams Lake, 150 Mile House, Chimney Lake, Dog Creek, Riske Creek Soda Creek, Rose Lake, Horsefly/Likely, and Big/Beaver Lake
- Northern Region
    - Southern Quesnel, Nazko, Bouchie Lake, and Barlow Creek

- Western Region
  - Big Creek, Gang Ranch, Alexis Creek, Tatla Lake, Anahim Lake, and One Eyed Lake

Outside project scope & study limitations

Although a small number of dam sites were visited, the project scope did not include detailed assessment or inspection of individual agricultural dams. Project scope also didn't involve evaluation of the physical infrastructure or technical issues with individual dams. Therefore, the study does not provide solutions that are specific to individual dam owners and instead focuses on shared issues and concerns. The scope did not include evaluation of the provincial *B.C. Dam Safety Regulation* or the B.C. Dam Safety Program.

The inventory is limited in a few key respects. Although the inventory contains a significant number of dams, it is likely that there are agricultural dams in the Cariboo region that are not included (reflecting the same gaps in Ministry of Forests Lands and Natural Resource Operations public database). In addition, although the consultation included 42% of dams, only 14% of dam owners were consulted.

Wetland classification and species at risk data were acquired as spatial shapefiles from public sources (DataBC) and analyzed using ArcMap. A buffer of 500 m was used from the inventoried location of the dam to identify any intersection with wetlands or species at risk. Wildlife habitat areas were initially investigated using the same technique. However, the available spatial data did not contain the detail necessary to complete the analysis using that approach . As an alternative, the wildlife habitat areas were individually reviewed using the DataBC web service iMap (DataBC, 2015) to identify wildlife habitat areas, associated species, and presences of any agricultural dam or reservoir within or intersecting the areas. This approach was possible since the number of habitat areas and affected dams was relatively small.

1.1.1 Climate change impacts review

A climate change impacts review was conducted to verify the expected influence of climate change on agricultural water storage requirements as well as dam operation and safety. Existing studies, reports, and data were reviewed to identify key criteria of interest, gaps and areas requiring additional study. To explore more locally relevant examples of expected impact to stream flow regimes, projected climate change effects were analyzed for three small watersheds upstream from representative agricultural dams: McGhee Lake dam, Dragon Lake dam, and Chris Lake dam. A summary of impacts is presented in the report; the details of the local analysis may be found in **Appendix C**.

1.1.2 Agricultural Dam Inventory

The intent of the dam inventory was to establish the distribution of agricultural dams in the Cariboo. The base data for the inventory was generated from the Ministry of Forests, Lands and Natural Resource Operation's (MFLNRO) public dam database available from DataBC (Government of British Columbia, 2015a). This supplied the general information associated with the dams, such as name, owner, location, height, length, and elevation.

The consequence classification of dams is not included in the provincial public database and therefore, classifications had to be acquired directly from MFLNRO. Any dams not included in the list supplied by MFLNRO were given a rating of Unknown and the remaining dams were classified as Very High, High, Significant, Low or Undetermined, as indicated by the MFLNRO data.

In addition to information obtained from MFLNRO, the following was included in the inventory:

- Agricultural sub-region (using the sub-region classification developed for the project);
- Land ownership status of the dam location, indicating private or Crown, whether within the Agricultural Land Reserve (ALR), and whether on First Nation reserve land;
- Consultation information including dam owner concerns about water yield, storage opportunities, tourism and recreation opportunities, openness to collaboration, Operations, Maintenance and Surveillance (OMS) Manual and Dam Safety Review (DSR) information, and whether considering decommissioning;
- Proximity of dams to parks, highways, or municipalities; and
- Identified wetland riparian classes (description of common wetland ecosystems in BC), wildlife habitat areas, and endangered and sensitive species.

Concerns and issues with the dams were identified through one-on-one consultations with dam owners (presented in section 4.2). Secondary benefits generated by dams (e.g. recreation or habitat) were also established through consultations, as well as available GeoBC and DataBC spatial data. Spatial data helped to determine factors such as land use, proximity to parks, highways, and municipalities (i.e. accessible or isolated site, potential use for fighting wildfire), wetland riparian classes, wildlife habitat areas and proximity to sensitive and endangered species (Government of British Columbia, 2015b).

Private and Crown land data for the Cariboo region was acquired from the Integrated Cadastral Information Society (ICIS), obtained through the BC Ministry of Agriculture. This data only includes surveyed land parcels. Any dam located on unsurveyed land was assumed to be on Crown land.

Specific links to the direct download sites for the data acquired from DataBC and GeoBC can be found in Section 8, References.

Due to the limitations of the inventory – and a commitment to confidentiality made to dam owners participating in the consultations – the inventory is not included in the report and will not be made publically available. It was primarily intended to serve as a background document to inform this report and whenever possible, inventory data has been aggregated and summarized to assist in drawing general conclusions.

1.1.3 Consultations & site visits

Consultation participants

The inventory was supplemented with dam owner consultations and site visits. The majority of the consultation participants were cattle ranchers who own dams that store water for irrigation and stock watering. Ducks Unlimited Canada (DUC) was also considered an important contributor to the project, as it owns or manages over 120 dams throughout the Cariboo region. DUC staff are able to provide insights about water availability, challenges facing dam owners, and the advantages and disadvantages of multi-stake holder agreements with respect to dam operations and maintenance.

Consultation participants were chosen based on the consequence classification of their dam(s), dam location(s), interest of the dam owner in the project, the number of dams owned or managed, and recommendations from the project management team. The Cariboo Cattlemen's Association acted as a liaison to initiate contact with many of the agricultural dam owners. Local Ministry of Agriculture staff provided knowledge of the primary agricultural regions in the Cariboo and also aided in selecting and contacting participants for the consultation process.

Of the 403 dams in the inventory, 168 were considered in the consultation of dam owners, amounting to approximately 42 % of the total dams. A total of 24 dam owners, or 14 % of all owners, were included in the consultation (including Ducks Unlimited Canada). **Table 1** shows the numbers of dams in each agricultural sub-region included in the consultation.

In order to keep details about individual dams confidential, only aggregated information is included in this report; dam inventory information is not linked with specific dam locations or owners, unless authorized by the dam owner. Consultations were spread throughout the agricultural sub- regions to provide an understanding of the problems facing the owners throughout the various climatic regions of the Cariboo.

Consultation process

NHC compiled a set of questions and talking points to guide the discussions with dam owners. This style of consultation allowed for more open conversations about the sites and encouraged the owners to ask questions about the study. The discussion guide document was refined throughout the project, but discussion themes remained consistent. The discussion guide document is attached as **Appendix B**.

Consultations were primarily completed over the phone. Some consultations occurred via email (if requested by the dam owners) and a few consultations were completed in-person during site visits or if participants were willing and available to meet.

Consent forms were sent to participants following the consultation. The forms explained the study, as well as how information provided by participants would be used. Participants were instructed to sign and return consent forms only if they did *not* agree with terms provided in form and wanted their information removed.

Communication with relevant agencies

Through discussions of the project with the local Dam Safety Officer and the Regional Water Branch Manager (MFLNRO) it was understood that FLNRO was concerned about the number of high consequence classified dams that were in need of a Dam Safety Reviews within the region, and the expectation that enforcement, under the Dam Safety Regulation, would be required. It was also apparent that, under current policy direction, the Dam Safety Officer is primarily tasked with a role of enforcing compliance to prevent future dam failures and not with collaborating with or supporting dam owners. Specific information about the requirements for Dam Safety Reviews (DSRs) was discussed and incorporated into the study.

Multiple discussions were held with staff from Ducks Unlimited Canada (DUC), as well as with local staff from the Ministry of Agriculture. Ducks Unlimited Canada staff provided information about the dams that they own, collaborative/cost-sharing approaches, existing approaches that DUC uses to inspect and maintain their dams and challenges with dam ownership. Ministry of Agriculture identified potential sources of data and assisted with identifying dam owners for participation in the consultation.

The Cariboo Regional District (CRD) was contacted to discuss cost sharing models that might involve an active role for the CRD; such as multi-user cost sharing models or gaining efficiencies through collaboration between multiple dam owners (**Section 6.4**). While this exchange didn't necessarily explore the full range of possibilities, the CRD expressed concerns about taking a leadership role with agricultural dam maintenance and upgrades due to a lack of capacity and resourcing, as well as liability issues.

Site Visits

A very small sample of the dams included in the consultation were visited by NHC. The eight site visits were not formal inspections, but were used to help to verify and evaluate the data gathered during the inventory and consultation processes, and to collect any additional information about the dams. Information gathered during the site visits included dam condition, outlet structure condition, reservoir features (i.e. signs of existing development, recreation, or wildlife use or values), downstream conditions, and future storage opportunities.

Sites were selected to view dams under a range of circumstances including a dam that was recently upgraded, a dam with potential for cost-sharing collaboration, and a dam where increased water storage may be a future option. Some of these sites are featured in Case Examples provided later in the document.

Site visits and consultations by location (sub-region) are presented in **Table 1**.

Table 1: Number of dams covered in consultation and number of dam site visits within agricultural sub-regions

Agricultural Sub-Region	No. of Dams in Consultation	Percent of Total Dams in Consultation	No. of dams in Sub-Region	Percent of Dams in Sub-Region in Consultation	No. of Dams Visited
100 Mile/Lac La Hache	29	17%	57	51%	1
150 Mile	27	16%	36	75%	3
Alexis Creek	1	1%	8	13%	
Anahim Lake	5	3%	6	83%	
Barlow Creek	0	0%	3	0%	
Big Creek	29	17%	31	94%	
Big Lake/Beaver Lake	5	3%	17	29%	
Bouchie	0	0%	1	0%	
Canim Lake	0	0%	7	0%	
Chimney Lake	1	1%	20	5%	
Dog Creek	10	6%	26	38%	
Gang Ranch	0	0%	2	0%	
Horse Lake/Bridge Lake	6	4%	24	25%	
Horsefly/Likely	0	0%	5	0%	
Nazko	2	1%	3	67%	
One Eyed lake	1	1%	2	50%	
Riske Creek	26	15%	39	67%	2
Rose Lake	3	2%	17	18%	
San Jose	13	8%	31	42%	1
Soda Creek	4	2%	16	25%	1
Southern Quesnel	6	4%	20	30%	
Tatla Lake	0	0%	18	0%	
Williams Lake	0	0%	14	0%	
Total	**168**	**100%**	**403**		**8**

1.1.4 Dam regulation requirements and associated costs

Description of the regulatory requirements is based on the *B.C. Dam Regulation* (2000/2011) and associated background documents; most of which are available from the BC Dam Program webpage (BC Water Management Branch Dam Safety Section 2011a, 2011b, 2012, 2013, 2015), and MFLNRO (2014). Additional supporting materials regarding dam safety (such as Canadian Dam Association *Dam Safety Guidelines*) were also referenced.

The costs associated with meeting the regulatory requirements for surveillance and maintenance of small dams were developed based on hourly rates estimated for the owner or a third party contractor or engineer to complete the work. The rates are based on past projects and discussions with local personnel. The estimated costs should be considered approximate. Actual costs could vary substantially depending on site location, location of third party support, status of existing process and documentation for surveillance and maintenance. Costs for maintenance and surveillance are presented in greater detail in **Section 3.1**.

1.1.5 Identification of key issues and solutions

Key issues and solutions were drawn primarily from consultations with the individuals involved with agricultural dams in the Cariboo region (either as owners or with agencies with related mandates) in the regions. NHC consultant background experience with local dam issues and owners also informed this section of the report, as did the knowledge and experience of the Project Committee.

2 CLIMATE CHANGE & AGRICULTURAL DAMS

Over the twentieth century, the southern half of British Columbia has seen a trend towards warmer and wetter conditions, with diminished snowpack and glaciers – conditions that have resulted in greater streamflow variability from year to year (Déry et al., 2012). Between 1895 and 1995, mean annual air temperature has risen by about 1°C, and warming in winter and spring in the southern interior of British Columbia has surpassed this average (Fraser and Smith, 2002).

In some Cariboo watersheds (such as the Quesnel watershed) glacier melt is the source of summer streamflows (e.g., Burford et al., 2009). An analysis of August streamflows in British Columbia found significant widespread decreasing trends for glacierized catchments, although not for catchments without glaciers (Stahl and Moore, 2006).

Based on projections provided by the Pacific Climate Impacts Consortium, the *Cariboo Adaptation Strategies* identifies three main changes in climate that are relevant to the future of agricultural water storage in the region:

1) Average annual temperature is projected to increase, with the greatest increase in summer.
2) Extreme heat events (summer) and extreme rainfall events (winter/shoulder seasons) are projected to increase in frequency and intensity.
3) Annual average precipitation is projected to increase slightly – this increase will be concentrated in the winter with both summer precipitation and winter snowfall projected to decrease.

The above changes are anticipated to affect watersheds which will shift toward rain-dominated flow regimes, leading to increased variability (and less predictability) in timing and volume of flows. The combined effects will result in an increased need for agricultural water storage during periods when water supply is decreasing. At the same time, the challenges associated with dam operation and infrastructure will also grow. **Figure 1** shows the anticipated changes and their potential impacts to agricultural dams.

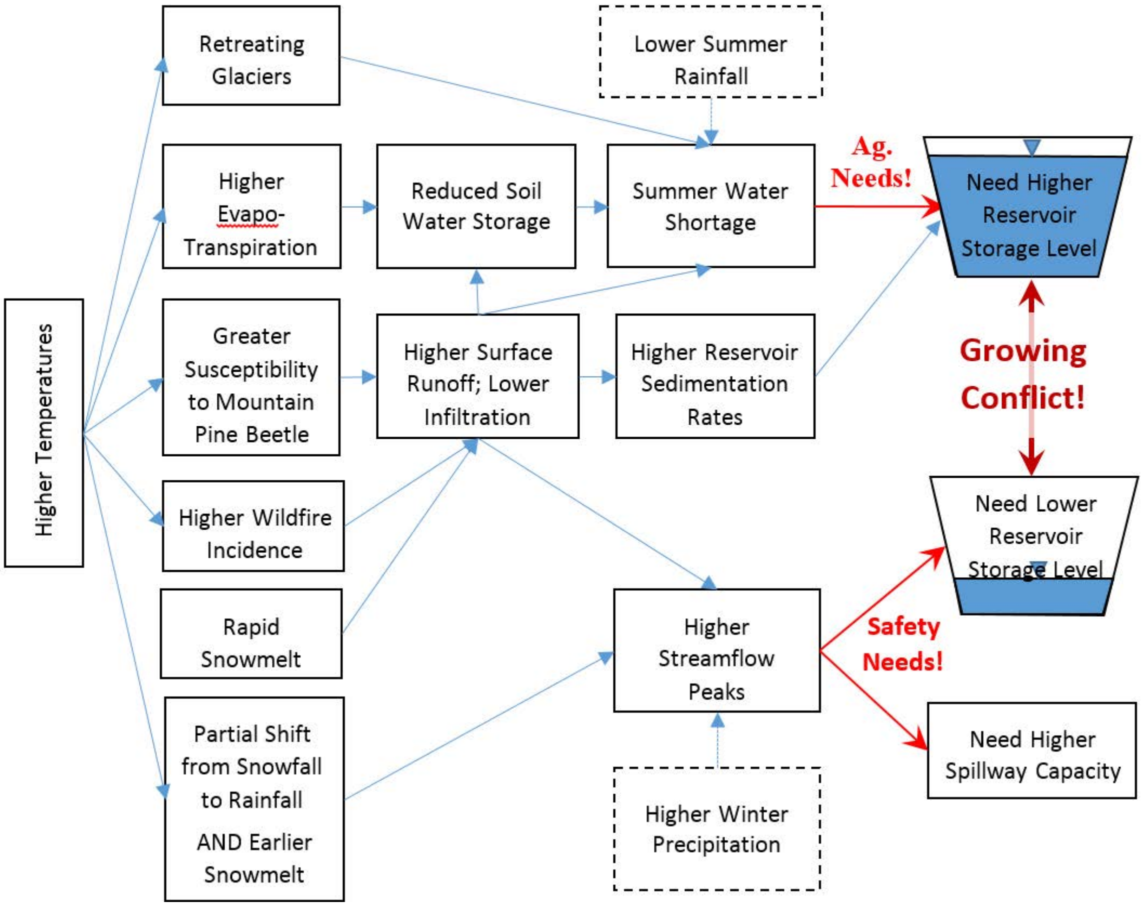


Figure 1: Potential consequences of climate change for agricultural dams in the Cariboo region. *Dashed boxes represent future precipitation trends indicated by several, but not all, Global Climate Models.*

As part of this project, potential climate change effects were analyzed for three small watersheds upstream from three representative agricultural dams – McGhee Lake dam, Dragon Lake dam, and Chris Lake dam. The detailed findings of this analysis are presented in **Appendix C**.

2.1 Impacts related to Agricultural Dams

Based on the findings of previous studies, as well as the analysis in **Appendix C**, the following summarises some of the anticipated impacts of climate change to the Cariboo region's agricultural dams:

- Higher temperatures and longer dry periods during summer are likely to decrease water supply and increase the need for water storage and yield capacity of agricultural dams.
- Higher temperatures and less frequent precipitation are anticipated to increase the risk of wildfire events. Wildfires can have long-term impacts on soil, vegetation and runoff hydrology in watersheds and fire-fighting could compete for water supplies.

- The timing and volume of peak runoff flows may have negative impacts on agricultural water storage, as the early season flows may not coincide with the growing season.
- Earlier and greater freshet flow is expected to result in increased flooding, erosion, debris supply, and channel changes.
- Greater freshet flows could lead to increased flow requirements for spillway capacity and dike crest elevation.
- Increased variability and changes in timing of streamflow may make operation of dams more difficult. This is most likely to occur where dam operation is integrating multiple objectives such as flood control, habitat (water fowl, fish, amphibians), recreation, irrigation and/or livestock water.
- Higher winter temperatures and greater fluctuations in temperature and precipitation could pose a risk to the operation, and the integrity, of hydraulic structures such as dams and spillways. Fluctuating freeze thaw cycles could lead to destructive breakup processes.
- Changes in climate could further alter operation and maintenance requirements through changes in vegetation growth (terrestrial as well as emergent and submergent vegetation), increased animal burrowing activity, and increased debris flows blocking spillways.

3 REQUIREMENTS OF DAM OWNERSHIP IN BC

In British Columbia, ownership of dams for agricultural purposes falls under the *B.C. Dam Safety Regulation* (2011) of the Provincial *Water Act*. The Canadian Dam Association's (CDA) *Dam Safety Guidelines* (2007) provides guiding principles for the management of dams (see **Appendix D**). Although the CDA *Dam Safety Guidelines* has no legal status, it is considered the primary technical document for performing DSR's in Canada (Professional Engineers and Geoscientists of BC, 2014).

There are over 2,000 water supply dams in British Columbia that are regulated by the provincial government. Small dams (under 10 m in height) make up 90 % of these dams (MFLNRO, 2015). Dam use varies across a range of water needs, but agriculture is considered one of the main uses in the province.

The Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) regulates these structures through the 2011 *B.C. Dam Safety Regulation* and the Dam Safety Program, which was updated following the Testalinden Dam failure, south of Oliver, BC, in 2010. After this event, MFLNRO initiated a Rapid Dam Assessment process, identifying non-urgent follow-up requirements on over 450 dams in BC. Although the regulated requirements were not substantially changed with the 2011 update, it marked a shift in the approach to dam safety practices in B.C. and led to the Dam Safety Program that exists today.

The *Water Act* is scheduled for replacement in 2016 by Bill 18 *Water Sustainability Act*. The provincial government intends to replace the *B.C. Dam Safety Regulation* with a new regulation authorized under the *Water Sustainability Act*. A number of the proposed operational changes may improve application of the regulation by clarifying information requirements; including giving greater discretion to the

Comptroller or Regional Manager on the type of independent expert opinion a dam owner can be required to draw on under different circumstances; and effectively broadening the types of authorized professionals allowed to carry out reviews and oversee invasive dam investigation procedures.

Other proposed changes to the *B.C. Dam Safety Regulation* will add greater responsibility to dam owners, including requiring all dam owners (regardless of any dam height, storage capacity or failure consequence classification) to review downstream conditions on an annual basis and to reassess the consequence classification. Under the current regulation, certain dams with low consequence classification are exempt from this requirement. Furthermore structures retaining both groundwater and surface water will be considered dams (instead of dams being limited to structures retaining surface water) as will agricultural dug-outs that can maintain a water level above the adjacent ground on one or more sides and meet the definition of a dam (see definition below).

Definition of a Dam

The current regulation applies to dam structures that meet one of the following criteria regarding height, storage capacity and/or consequence classification:

- Equal to or greater than 1 m in height and with a maximum storage capacity greater than 1,000,000 m^3;
- Equal to or greater than 2.5 m in height with a maximum storage capacity greater than 30,000 m^3;
- Equal to or greater than 7.5 m in height; and
- Any dam with a dam failure consequence classification of Significant, High, Very high, or Extreme.

Dam height is measured from the top of the crest to the natural stream bed or lowest downstream elevation outside the limit of the dam. Dams that fit any one of these criteria are regulated dams and all others are non-regulated. As noted above, within in the current regulations a dam definition includes only structures that store water from a stream. With the proposed changes to the *B.C. Dam Safety Regulation*, this definition is set to expand to include structures that capture groundwater (impound water from an aquifer).

Dam Ownership

A dam owner is defined as the current or most recent license holder or land owner (if there is no license holder). Dam owners are required to operate the dam in accordance to the *Dam Safety Regulation* and their license of approval as well as any specific order, emergency preparedness plan, or operation, maintenance, and surveillance manual for the dam.

Consequence Classification

The dam failure consequence classification is based on the potential downstream impacts associated with a failure of the dam. Dam failures can result in torrents of water, mud and debris moving into the catchment downstream of the dam. Consequence classifications reflect the potential extent of loss, deterioration and/or damage in the following areas:

- Human life
  - Population at risk (numbers) and whether it is temporary or permanent risk
- Environmental and cultural values
  - Fisheries habitat or wildlife habitat
  - Rare or endangered species
  - Unique landscapes or sites of cultural significance
- Infrastructure and economics
  - Infrastructure
  - Public transportation or services
  - Commercial facilities
  - Residential buildings and areas

More detail regarding consequence classifications are provided in the *B.C. Dam Safety Regulation*.

3.1.1 Dam Safety Management System

The Dam Safety Management System (DSMS) is the system that is used to ensure dam safety, including the overarching policy, plans, procedures and the steps dam owners are required to take to maintain their dams to the required standard. Within the DSMS, the information that must be provided on an dam varies, depending on its downstream consequence classification, but there are requirements applying to all regulated dams (over 85% of the agricultural dams in the Cariboo region). The DSMS includes the design, construction, and procedures for operation, maintenance and decommissioning of dams.

The major components of a DSMS are outlined in the Regulation and are summarised in **Tables 2** through **4**. The elements of DSMS include operation, maintenance and surveillance, detailed assessments and investigations potentially required during a Dam Safety Review, and physical upgrades.

Site surveillance is defined as monitoring of the dam through regular visual inspections, and collection, analysis and interpretation of data, as required. Formal inspections involve a thorough on-site inspection of dam, including all attributes, such as the outlet, embankments, spillways, scour and erosion protection, and maintenance concerns. Formal inspections are completed by either the dam owner or a representative responsible for dam safety (Government of British Columbia, 2011).

3.1.2 Frequency of Dam Safety Management System activities

An important aspect of the Dam Safety Management System is ensuring compliance with the Regulations. Minimum safety activities outlined in the Regulations and the required frequency of each activity (dependent on the consequence classification for the dam) are summarized in Table 2. Frequency of some activities may vary for individual sites; this would be defined in the individual dam owner's Operation, Maintenance and Surveillance manual (OMS).

Table 2: Frequency of activities for dams of varying downstream consequence risk (Government of British Columbia, 2011).

Activity	Frequency of Activities Based on Classification			
	Extreme	Very High and High	Significant	Low
Site Surveillance	Weekly	Weekly	Monthly	Quarterly
Formal Inspection	Semi-Annually	Annually	Annually	Annually
Monitor Instrumentation	Annually unless otherwise specified in OMS	Annually unless otherwise specified in OMS	Annually unless otherwise specified in OMS	If and when required by Dam Safety Officer
Test operation of outlet facilities, spillway gates and other mechanical components	Annually	Annually	Annually	Annually
Update emergency contact information in EPP	Annually	Annually	Annually	Not Applicable
Review and revise, if necessary the OMS and EPP	Every 7 years	Every 10 years	Every 10 years	Not Applicable
Conduct Dam Safety Review and submit report[1]	Every 7 years	Every 10 years	Not Applicable	Not Applicable
Review downstream conditions and notify Dam Safety Officer of any changes	Annually	Annually	Annually	Annually

[1]There are four types of Dam Safety Reviews; comprehensive, audit, detailed design and performance review. In almost all cases the Regulatory Authority expects that a comprehensive review will be required to meet the Regulation. An audit style review will not be accepted unless prior written approval has been provided by the Regulatory Authority.

3.1.3 Estimated Dam Operation and Maintenance Costs

Table 3 provides current cost estimates for the operation and maintenance of a typical earthfill dam less than 5 m high. Costs are dependent on dam location, size, condition, age, and extent of recent upgrades. Costs may vary beyond the estimates shown, depending on the level of reporting and documentation that exists for an individual dam.

The requirements and cost for surveillance, reporting, and safety review are dependent on consequence classification, as outlined by the *B.C. Dam Regulation*. Cost for the initial development of an OMS, Emergency Preparedness Plan (EPP) and Dam Safety Review may be greater depending on the current state of knowledge about a dam.

The cost associated with Dam Safety Reviews are dependent on the condition of the individual dam, its age, extent of recent upgrades, and the availability and state of any design and/or assessment records.

As a result, further studies and investigation may be required to determine whether a dam meets the requirements of the Dam Safety Regulation.

Table 3: Estimated annual Dam Safety Management System costs per dam (conducted by owner or by third party).

Dam Consequence:		Very High and High		Significant		Low	
Activity	**Conducted**	**Frequency**	**Cost**	**Frequency**	**Cost**	**Frequency**	**Cost**
Surveillance	By owner	Weekly[1]	$ 1,300	Monthly[1]	$ 300	Quarterly[1]	$ 100
	By third party	"	$ 5,200	"	$ 1,200	"	$ 400
Formal Inspection	By owner	Annually	$ 100	Annually	$ 100	Annually	$ 100
	By third party	"	$ 1,200	"	$ 1,200	"	$ 1,000
Instrument Monitoring *(if applicable)*	By owner	Annually[1]	$ 100	Annually[1]	$ 100	If required	$ 0
	By third party	"	$ 1,200	"	$ 1,200	"	n/a
Operations Test	By owner	Annually	$ 25	Annually	$ 25	Annually	$ 25
	By third party	"	$ 500	"	$ 500	"	$ 500
EPP Contact Info Update	By owner	Annually	$ 50	Annually	$ 50	n/a	0
	By third party	"	$ 300	"	$ 300	"	n/a
OMS Update	By owner	Every 10 years	$ 50	Every 10 years	$ 50	n/a	n/a
	By third party	"	$ 500	"	$ 500	"	n/a
Emergency Preparedness Plan Update	By owner	Every 10 years	$ 50	Every 10 years	$ 50	n/a	n/a
	By third party	"	$ 350	"	$ 350	"	n/a
Dam Safety Review[4]	By third party	Every 10 years	$ 1,400	Every 10 years	n/a	"	n/a
Classification Review	By owner	Annually	$ 100	Annually	$ 100	Annually	$ 100
	By third party	"	$ 600	"	$ 600	"	$ 600
Estimated Annual Costs per Dam	**By owner**	**per annum**	**$ 3,175**	**per annum**	**$ 835**	**per annum**	**$ 345**
	By third party	**per annum**	**$ 11,250**	**per annum**	**$ 5,850**	**per annum**	**$ 2,700**

Note 1: Lower frequency may be permitted if rationalised and stated in an OMS agreed upon by a Dam Safety Officer.

The costs presented in **Table 3** were derived based on estimated hourly rates of $25 for owner conducted work, $40 to $50 for locally hired contractor, and $120 to $190 for engineering. It is assumed the site work can be scheduled to be done while in the area with approximately 30 km additional travel (one way) for the contractor and 60 km (one way) for engineering. Other assumptions are as follows:

- Surveillance is to be done by the owner or a local contractor.
- Formal inspections are to be done by the owner or engineer/engineering technician in conjunction with routine surveillance. Instrumentation monitoring (if applicable) and operations tests are expected to be done during the formal inspection.

- Emergency Preparedness Plan (EPP) contact updates , plan updates, and Operation, Maintenance, and Surveillance (OMS) updates are to be done concurrently by the same party. It is assumed that site inspection is not required for these tasks.
- Dam Safety Review (DSR) costs assume that this is undertaken by a professional engineer (as required by the regulations), and that the engineer was also involved with recent formal inspection, operations tests, EPP updates, and OMS updates for the dam. Alternatively additional cost will be required by the engineer to review the documents and inspect the dam. In addition, it is assumed that documentation and record keeping for the dam are up to date. If adequate records are not available, DSR costs can go beyond $10,000 to $60,000 depending on the need for additional studies.
- Classification review cost assume that the review consists of reviewing past consequence classifications and any changes that may have occurred since the previous review. The cost of consequence classification can be substantially greater if additional study is required to assess the consequence classification (e.g. conducting a breach analysis and downstream inundation assessment). Therefore, costs are dependent on the extent of study required downstream, presence of existing data (i.e. recent survey, maps, air photos), what is potentially triggering the classification (residents, infrastructure, environment, or cultural values).

Table 4 outlines some of the additional studies that may be required during, or following, the completion of a Dam Safety Review (DSR). DSRs are only required on High, Very High and Extreme consequence classified dams (Government of British Columbia, 2011). The studies may be requested by the engineer conducting the DSR, or by the reviewing Dam Safety Officer. The decision to require additional study could be based on the condition of the dam, or the lack of documentation or knowledge. Factors that will affect the cost of the studies have been included to provide insight into how costs may be determined. The cost of additional studies are approximated from past studies for relatively small earth dams (<5 m high) within relatively simple upstream watersheds. Additional studies for larger, more complex structures, or more complex watersheds can be substantially greater than the costs presented.

Table 4: Estimated costs of additional studies and investigations potentially required during detailed Dam Safety Review for High and Very High consequence classified dams.

Activity	Trigger Example	Range	Cost	Factor
Hydrotechnical Assessment	MFLNRO or engineer conducting the DSR are not satisfied with the available information on design flows or spillway capacity. Design flows may have changed since last DSR or assessment.	From To	$ 5,000 $ 20,000	Complexity in catchment or reservoir spillway control or operation
Geotechnical Assessment	Insufficient existing information, and the DSR Engineer or MFLNRO recommends further geotechnical investigation.	From To	$ 5,000 $ 20,000	Lack of design or construction records
Seismic Assessment	The basic seismic assessment recommended by MFLNRO (on their dam safety website) is deemed to be insufficient for the particular dam so a more detailed assessment is requested.	From To	$ 3,000 $ 12,000	Location relative to seismic activity and subsurface information
Hydrological Assessment	The size of Inflow Design Flood (IDF) or other information is questioned by the DSR Engineer or MFLNRO; there is a lack of previous design flow, a simplified or erroneous approach to previous design flow, or potentially changed design flow	From To	$ 5,000 $ 15,000	Complexity of watershed, size of reservoir, and dam operation
More Detailed Classification Review	MFLNRO or the dam owner contests the consequence classification that has been assigned to the dam or the downstream channel has changed (i.e. development downstream). Detailed studies would include channel and floodplain survey, breach analysis, and downstream inundation mapping.	From To	$ 5,000 $ 20,000	Length of downstream river reach potentially affected. Survey Requirements.

Dam Safety Review findings can classify a dam as reasonably safe; however, deficiencies or non-conformances may still be identified. The Dam Safety Officer will require that upgrades be completed to resolve any deficiencies associated with the dam. The estimated costs for specific upgrades are summarised in **Table 5**. The costs are approximate values based on similar projects throughout the province. The height of the dam, and occasionally the length, can substantially influence the cost of the upgrades. Other factors that can affect the cost of the upgrades have been included for reference.

Table 5: Estimated costs for upgrades based on generic deficiencies potentially identified through a DSR, dam audit, or routine surveillance and maintenance.

Dam Consequence:			Very High and High	Significant and Low	Factor
Activity	**Trigger Example**	**Range**	**Cost**	**Cost**	
Improve Spillways	Where spillways are in poor state of repair or cannot pass the Inflow Design Flood (IDF).	From To	$ 1,000 $ 50,000	$ 1,000 $ 10,000	Size of IDF and condition of existing spillway
Upgrade Low Level Outlet Structure	Where the conduit is degraded or leaking.	From To	$ 3,000 $ 15,000	$ 3,000 $ 10,000	Type and condition of existing outlet
Increase Dam Height or Flatten Slopes	Where freeboard is inadequate or dam wall slopes are too steep to be safe.	From To	$ 1,000 $ 10,000	$ 1,000 $ 10,000	Size of IDF, condition of dam embankment, and availability of materials
Geotechnical Upgrades	Where foundation or abutment leakage is threatening the safety of the dam structure.	From To	$ 4,000 $ 100,000	$ 4,000 $ 30,000	Extent of leakage and condition of dam embankment
Seismic Upgrades	Where the current structure cannot withstand the required earthquake ground accelerations without failing.	From To	$ 4,000 $ 100,000	$ 4,000 $ 30,000	Condition of existing embankment and location relative to seismic activity
Access Upgrades	In the case of emergencies (e.g. to get to the dam to open valves, make rapid repairs, etc.) it is important to have good road access to the dam.	From To	$ 5,000 $ 20,000	$ 5,000 $ 20,000	Condition and extent of existing access
Safety Upgrades	Public safety concerns; walkway railings; fencing; booms; signage.	From To	$ 1,000 $ 10,000	$ 1,000 $ 10,000	Type of dam and location relative to public access.

Based on the estimates provided in **Tables 3-5** , it is possible that an owner of a High Consequence dam in the region – that has not been upgraded in the past 15 years – could incur costs as high as $40,000 to conduct the Dam Safety Review with all associated studies and investigations. An additional $150,000 could be required for the necessary upgrades. Therefore, in order to maintain the current level of agricultural water storage, 21 dam owners in the Cariboo region could be shouldering up to $5,000,000 in dam studies and upgrades over the next 5 to 10 years.

4 INVENTORY SUMMARY

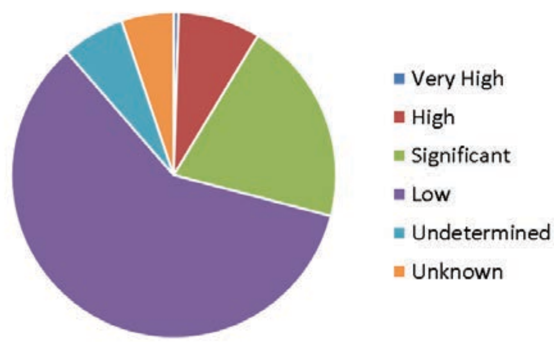
There are a total of 403 dams were identified in the inventory, including active, breached, decommissioned, and not constructed (sites that have applied for water licences, prior to dam construction) dams that are within the agricultural sub-regions.

4.1.1 Descriptive Dam Summary

The information collected and summarised in the dam inventory was assembled in a spreadsheet (Microsoft Excel) and spatial database (Esri ArcGIS). A map showing the locations of dams included in the inventory is included in Appendix A. The findings from the collated information about dams within the study area are summarised below.

Consequence Classification:

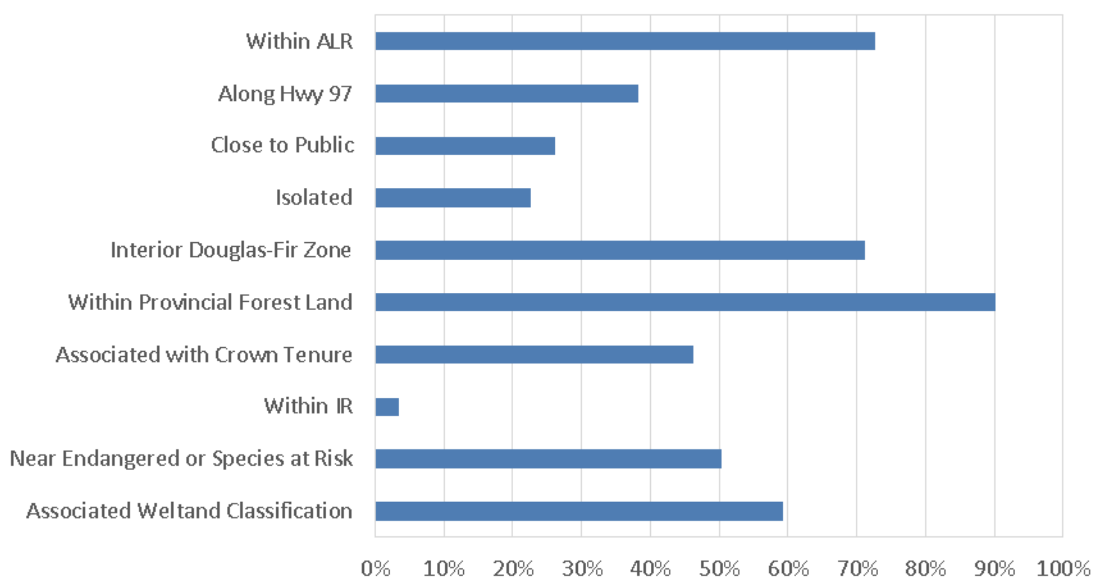
- Very High consequence = 2 dams (0.5 %)
- High consequence = 33 dams (8 %)
- Significant consequence = 82 dams (20 %)
- Low consequence= 240 dams (60 %)
- Undetermined = 25 dams (6 %), and
- Unknown = 21 dams (5 %).



Note: Dams with an undetermined consequence classification are also indicated as unregulated dams in the public data base, which suggests they do not meet the definition of a dam covered under the Dam Safety Regulation. The Unknown category means the consequence information was not available; this category also includes one dam under construction and two breached dams.

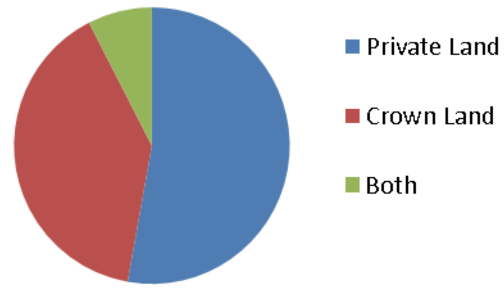
Location

- 73 % of the dams are located within the ALR;
- 38 % of the dams in the study area are located along the Hwy 97 corridor, including the 100 Mile/Lac La Hache, San Jose, 150 Mile House, Williams Lake, Soda Creek, and Southern Quesnel sub-regions;
- 26 % of dams are classified as accessible; located 2 km or less from highways, parks, or municipalities (although not all of these dams are verified as accessible, they are relatively close in location to other people and therefore may be - or could in the future be - providing noticeable benefits of value to other people);
- 23 % of dams are considered to be isolated; located 10 km or further from parks, highways and municipalities; 10 high and 1 very high consequence dam are included in this designation;
- 3 % of dams are on IR (Indian Reserve) land;
- 50 % of dams fall within observed areas for species that are either endangered or at risk; and
- 59 % of dams have an associated wetland classification, indicating that these sites have previously been classified as wetland ecosystems (MacKenzie and Moran, 2004).



Private or Crown Land

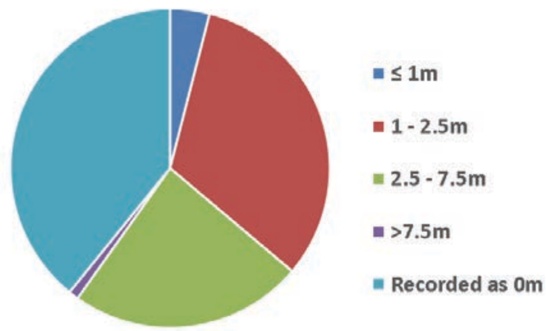
- 52 % of dam sites are on private land
- 46 % are on Crown land
- 2 % are on both Crown and private



Dam Height

- Greater than 7.5 m = 1 %
- 2.5 to 7.5 m = 20 %
- 1.0 to 2.5 m = 28 %
- Equal to or less than 1.0 m = 3 %
- 0 m (i.e. missing value) = 25 %

Of the dams with heights greater than 7.5 m (total of 4 dams), 3 are low consequence and 1 is high.



Non-Active Dams

- 23 % of dams in the inventory are non-active dams meaning there is a geo-spatial location noted, but the structure is either: abandoned, in application, breached, decommissioned, and or not constructed.

Type of Construction

- 93 % of dams are earthfill dams;
- Remaining dams are classified as buttress, concrete, dugout/pond, rockfill, steel sheet piles, or other.

Commissioning Date

- 7 % of dams have recorded commission dates; based on consultations with dam owners, it appears that dams without a commission date are generally *older* structures;
- Approximately 50 % of those were commissioned in 1985 or prior, suggesting the structures are 30 years or older;
- Approximately 30 % of those were commissioned 1975 or prior, suggesting the structures are 40 years or older;
- The oldest commission date is 1905;

- Despite the lack of readily available information on commissioning date it is expected that the majority of dams in the region are older than 40 years. This is based on review of a subset of the dams, local consultations, and from a familiarity of the dams in the region. The age of the dams suggests that without upgrades the associated infrastructure for many of the dams is beyond its lifespan; such aging infrastructure includes culvert outlets and flow control facilities.

Scheduled Audits

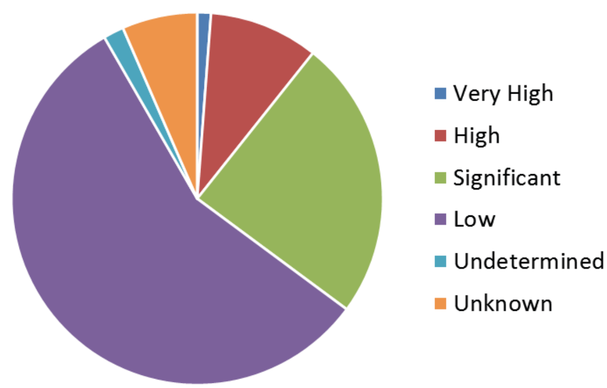
- 29 % or 116 of the dams have scheduled government audit dates (of 2016 or later).

4.2 Consultation Findings

As discussed in the Methodology section, consultation with a small sample of individual dam owners was undertaken to support the inventory and to help identify the primary issues faced by agricultural dam owners. Of the 403 dams included in the inventory, 168 were included in the consultation, amounting to approximately 42% of the total dams. A total of 24 dam owners or 14% of all owners were included in the inventory, including Ducks Unlimited Canada.

The set of consulted dams are composed of:

- 1% Very high consequence (2),
- 10 % High consequence dams (16),
- 24 % Significant consequence (41),
- 57 % Low consequence (95),
- 2 % Undetermined (3), and
- 7 % Unknown (11) [1]



The majority of dams considered in the consultation had heights less than 2 m. That is, 56 % of consulted dams had dam heights between 0 and 1.9 m, 38 % between 2 and 4.9 m, and 5 % were 5 m or greater - the highest being 11.5 m.

The participants were asked questions about water yield, water storage and water use; as well as DSRs and OMS systems and perceived potential for collaboration opportunities with other users. The following sections summarize the findings of the consultations.

Audits and Dam Safety Reviews

- 12 % or 20 of the consulted dams (across all consequence ratings) were reported as having received government audits over the span of ownership. This number does not include the

[1] Dams that did not have a consequence rating assigned in the data provided by FLNRO.

Ducks Unlimited Canada dams. Ducks Unlimited Canada reported that some of their dams have received government audits; however, the audited dams were not identified. Government audits are completed as part of the provincial dam safety program, to ensure owners are in compliance with the Regulation.

- A high proportion of the consulted dam owners reported concerns regarding a lack of (or poor quality) communication with the Dam Safety Officer prior to the audit. Generally, owners were not made aware of audits until after they were completed.
- Of the 16 high and 2 very high consequence dams included in the consultation, none have an accepted Dam Safety Review. DSRs have either not been completed or have been submitted and not accepted by the Dam Safety Officer.

Maintenance and Upgrades

- According to dam owners, preliminary DSRs and government audits, 3 of the 18 consulted high or very high consequence dams were known to require major upgrades with regards to seismic, spillways, or low level outlets.
- 1/3 of consulted owners reported concerns with maintenance on their dams, this includes difficulties with following an OMS manual. The majority reported that maintenance was incorporated into their regular work.

Water Yield Concerns

- Water yield concerns were associated with 23 % of dams covered in the consultation, with 42 % of those dams being located in the 100 Mile/Lac La Hache sub-region.
- 5 % of dam sites were reported to have potential for increased storage. Generally, would be achieved by increasing the height of the existing dam or restoring breached or decommissioned dams.
- 15% of dams that are being considering for decommission stated that this was due to low water yields (these sites are composed solely of Ducks Unlimited Canada sites). Only 2 of the consulted owners implied that they would likely decommission their dams to avoid the future costs associated with studies and upgrades.

Potential Collaboration

- 63% of consulted owners were interested in some type of collaboration opportunity to share costs.
- 83% of dams covered under the consultation were reported as providing other values on their reservoirs, such as water and waterfront access for residential housing, recreation, or wildlife habitat. The additional values produced by dam reservoirs, and identifiable resource beneficiaries may offer some potential opportunity to share the cost of dam ownership.

- 63% of consulted dam owners expressed interest in having a single entity to support dam ownership (i.e. to provide the opportunity to pool resources and as a group provide maintenance, inspections, and upgrades to the dams).

5 PRIORITY ISSUES & POTENTIAL SOLUTIONS

Agricultural dams in the Cariboo region are diverse with respect to location, age, condition, consequence classification and available water yield. Although each dam is unique, through the inventory, consultation and background research, a series of common issues emerged; primarily pertaining to meeting the requirements of the B.C. Dam Safety Program or to water yield. The priority issues and potential solutions have been divided into the following four categories with details provided below:

- Dam Safety Management System
- Dam Operation, Maintenance & Surveillance
- Dam Safety Reviews; and
- Water storage

A more detailed analysis of the most promising solutions follows in Section 6.

5.1 PRIORITY #1: Dam Safety Management System

The Dam Safety Management System (DSMS) is the system that is used to ensure dam safety, including the overarching policy, plans, procedures and the steps dam owners are required to take to maintain their dams to the required standard. The purpose of the DSMS is to reduce the public and environmental risk associated with dams. The requirements of a DSMS vary depending on the downstream consequence classification of a dam, but it is applicable to all regulated dams, or over 85% of the agricultural dams in the Cariboo region. The DSMS includes the design, construction, operation and maintenance and decommissioning of dams. The estimated costs associated with the preparation and maintenance of the DSMS are discussed in **Section 4** and are summarised in **Table 3.**

The primary identified issues related to the Dam Safety Management System include:

Knowledge/Information Gaps - During the consultation, a number of dam owners stated that they feel that they do not fully understand what the regulations require of them. Dam owners need improved knowledge of the various levels of dam inspection, the required documentation, and the operations, maintenance and surveillance that are required under the Regulation. Although a wide range of information and technical documents is available on the Dam Safety Program website, it is not currently being shared in a form that is proving effective and/or accessible for agricultural dam owners.

Shifting MFLNRO Role - In 2011, there was a shift toward a more enforcement-oriented approach in the oversight and regulation of B.C.'s dams. At present, this approach is leaving many dam owners to deal with identifying and addressing deficiencies with very limited guidance or support. In addition to gaps in knowledge transfer - some inconsistencies within the provincial Dam Safety Management program were raised by participants during the consultation process. It was noted that some dams were audited multiple times, whereas others had never been audited. Audits were also reported as having been undertaken without the presence of the owner, causing confusion and concern with owners who were only notified by mail after the audit was complete.

Costs associated with dam maintenance & upgrades – Operation and maintenance costs vary from site to site; however, overall costs are closely related to the dam's associated consequence classification. For some agricultural dam owners, the cost of the necessary reviews, studies and upgrades is greater than what can be financed through business operations and the option of decommissioning dams may have to be considered.

Table 6 summarizes these issues in more detail, identifies some potential solutions.

Table 6: Summary of Dam Safety Management System issues and potential solutions.

Issues	Related Issues	Possible Solutions
Knowledge and Information transfer (DSMS, ownership responsibilities)	Some owners not aware of their responsibilities as dam owners Some owners do not have an overarching dam safety management systems in place	Provide **training workshops** regarding DSMS and regulations. Provide owners with the **information needed** to develop their own system or contacts for individuals or companies who can provide this service.
	Some owners have limited knowledge of the Canadian Dam Association guidelines and BC Regulations	Prepare a **user-friendly version of the regulation**s for dam owners; provide necessary documentation in a form that doesn't require internet access.
MFLNRO Role	MFLNRO is taking on more of an enforcement role	Implement **mechanisms to improve communication** with dam owners.
	Inconsistencies in database and consequence classifications	**Review consequence classifications** to ensure that the specified classification is reflective of the site. Seek **continual improvement in the data quality** in the public database for better management of sites.
Costs associated with dam assessment, maintenance & upgrades	Dam owners may be struggling to cover costs of maintenance/upgrades and this could result in dams being decommissioned	Explore **options for collaboration** between dam owners. Seek out **opportunities to partner** with other dam owners and/or co-beneficiaries of dams including wildlife/recreational users.

5.2 Priority #2: Operation, Maintenance, and Surveillance

The Operation, Maintenance, and Surveillance (OMS) planning and practices assist dam owners to develop and document their approach to dam management, maintenance and monitoring. An OMS plan should provide owners and operators with guidance to ensure the safe operation of the dam (and to meet the requirements of the *B.C. Dam Safety Regulation*). Dams with downstream consequence classification of Significant or higher require an OMS manual.

The primary identified issues related to Operation, Maintenance and Surveillance of agricultural dams include:

OMS Manual Preparation and Implementation – Based on consultation input, formal OMS manuals have not been prepared for a large number of the dams in the Cariboo region. The roles and responsibilities associated with OMS are not always clearly defined and in some cases, owners are not aware of the requirements. Operator training in dam safety, OMS and emergency procedures has, in some cases, not been conducted.

In some cases, written records of OMS activities are not being kept by dam operators. Such records are important for Dam Safety Review as well as in the case of dam failure or injury on site. In such a situation, litigation may require records to prove that due diligence has been exercised in managing the dam.

Remote sites- 23% of the dams in the Cariboo region are remote with difficult or only seasonal access and poor communications. This prevents frequent surveillance - particularly in winter - and is expected to result in slow response in the event of an emergency. It is also more difficult to control dam site security and public safety at remote dams sites and vandalism is a problem for some owners.

Condition of Structures and Appurtenances – Some of the concerns with regards to the OMS of dams are related to spillways, low-level outlets, vegetation, monitoring equipment, and record keeping.

Table 7 summarizes these issues in more detail, and identifies some potential solutions.

Table 7: Summary of operation, maintenance, and surveillance issues and possible solutions.

Activity/Concern	Related Issues	Possible Solutions
OMS Manual Preparation and Implementation	Dam owners not familiar with requirements.	Deliver OMS **training workshops**
	OMS manual difficult to comply with or follow; requirements of OMS may not always be feasible or achievable for all sites.	Ensure OMS manuals are developed with **realistic expectations for individual sites.**
	Requirements for OMS dependent on consequence classification.	**Improve communication** between Dam Safety Officer and dam owners to help understand dam classification.
Remote Sites	Difficult access, especially during winter months (weekly or monthly surveillance required for some dams)	Incorporate (into OMS manuals) **consideration of site access** including options for few inspections when water levels are low.
	Slow response times to	**Upgrade access routes** to enable swift response to emergencies

Activity/Concern	Related Issues	Possible Solutions
	emergencies making it difficult to meet requirements of EPP.	or allow for a helicopter use.
	Remoteness results in challenges in controlling dam site security and public safety.	Install public safety **warning signs and upgrades to the outlet works** to prevent vandalism.
Condition of Structures and Appurtenances	Older/aging dam structure Deteriorating outlet structure	For high consequence dams, **complete recommendations from DSR**. For low or significant dams continue to **maintain and repair** structure, as required.
	Insufficient spillway capacity	For high consequence dams, complete recommendations from DSR. For low or significant dams, keep spillway clear of debris and install log boom.
	Costs of upgrades/repairs	Explore and implement **collaborative/partnership opportunities.**

5.3 Priority #3: Dam Safety Reviews

Dam safety reviews (DSRs) are an important part of the B.C. Dam Safety program. DSRs are designed as a methodical review and assessment of all aspects and systems of the dam that affect the dam's overall safety. DSRs are only required on dams with consequence classifications of High, Very High and Extreme (Government of British Columbia, 2011). This translates to approximately 32 agricultural dams (8%) included in the inventory. Although DSRs only affect a small portion of the entire inventory, the DSR process is rigorous and requires that the dam owner play an important role in completing the review. DSRs are required (under the Regulations) on Extreme Consequence dams every 7 years, and on all High and Very High consequence dams, every 10 years.

Depending on the individual site, differing levels of dam safety review may be required. For example, dams with previously completed DSRs or recently constructed dams may only require audit-type DSRs. Older dams with limited design or construction records are likely to need additional assessment and possibly further investigations (Association of Professional Engineers and Geoscientists of BC, 2014).

More study and investigation is typically required for older dams as they often lack adequate records to facilitate DSR completion; owners may not have a complete understanding of the requirements for record keeping. Inadequate record keeping has persisted despite the production of a number of documents[2] to help guide dam owners with keeping appropriate records; this may be a result of changes in government support/enforcement strategies and possibly dam owner uncertainty about which requirements apply. Inadequate record keeping for dams in not unique to agricultural dams.

[2] Documents that define record requirements include BC Dam Safety Regulation (2000/2011), BC Water Management Branch Dam Safety Section (2011a, 2011b, 2012, 2013, 2015), and MFLNRO (2014)

According to the Dam Safety Officer, only a few dam owners in the Cariboo have been able to have DSRs completed. Some of the issues that appear to be facing dam owners who are trying to complete DSRs include:

- Difficulty finding a qualified professional willing to conduct the DSR;
- Maintaining the necessary documentation required for the DSR;
- Changes in regional regulatory staff who may have differing interpretation as to the level of detail required for DSRs on small dams;
- Cost of having a DSR conducted, costs of any further investigations required for the DSR to be completed; and
- Cost of any upgrades identified as required during the DSR.

Currently it is unclear to dam owners, and to the engineers engaged to assist owners with DSR completion, how this situation might be resolved. In addition, the substantial liability involved in conducting DSRs has created an environment where few qualified professional engineers (QPEs) are willing to assist with undertaking DSRs. Once DSRs are completed, the process for approval is proving to be unclear and drawn out. For example, Ducks Unlimited Canada submitted two DSR's in May 2013, and these DSR's were subject to multiple reviews by the DSO and multiple rounds of edits by the DUC engineer; at this time, only one of the two DSR's originally submitted is now completed (it was completed in the summer of 2015). There is significant additional financial burden placed on dam owners when review processes are drawn out and engineers are required to be involved over long durations. The costs associated with DSRs and more detailed studies, along with the anticipated upgrades, can be substantial (see **Section 4 Tables 4 and 5**).

In some cases, the combination of challenges involved are leading agricultural dam owners to consider decommissioning High Consequence dams. At the time of this study, NHC was made aware of one High Consequence dam that has been decommissioned in the region, and another four that were being considered for decommission in the future.

The primary identified issues related to DSRs of agricultural dams include:

Table 8: Summary of Dam Safety Review issues and possible solutions.

Activity/Concern	Related Issues	Possible Solutions
Finding a Qualified Professional (QPEs)	MFLNRO is no longer providing feedback or guidance on DSRs and therefore QPEs must have the necessary experience to complete a DSR independently.	More **assistance** from Dam Safety Officers (working with consultants and owners) would help to **ensure acceptable DSRs and move processes forward**. Feedback is important for understanding the requirements of the DSRs.
	Liability and limited financial payback are disincentives to QPEs to being involved in conducting DSRs.	**Limit liability** either time (duration of liability with respect to study) and/or dollar value (relation to fees). Seek mechanisms to **top-up fees for qualified professionals**.
DSR Costs	Current requirements for engineers to state a dam is safe require extensive background information. There are insufficient resourcing available to complete the studies and upgrades needed to classify a dam as safe.	Undertake DSRs with **phased approach to collecting additional studies and implementing improvements** over time. Seek/create **alternative funding opportunities** to pay for DSRs.
	The requirements outlined in the APEGBC Guidelines and the Regulations require a comprehensive review of all design, construction, performance and safety management arrangements.	Provide more **information about how DSRs are reviewed** to aid consultants and owners in efficiently completing DSRs.
	Not all agricultural dam owners have the necessary records to complete DSRs, leading to more detailed, costly reviews.	**Local training and support for dam OMS and documentation**
Completing Necessary Upgrades	Older dams may require upgrades to meet hydrological and seismic requirements, low level outlets or head gate structures may also require repair. High risk dams in the Cariboo may not meet the requirements of the Regulations due to age	Seek out **cost sharing models** to help fund necessary upgrades.

Note 1: QPE – A qualified professional engineer is a professional engineer with the appropriate education, training and experience to carry out dam safety reviews including dam safety analysis described in the guidelines developed by the Professional Engineers and Geoscientists of BC (2014).

5.4 Priority #4: Water Storage

As identified in the *Cariboo Adaptation Strategies*, there are growing concerns about the availability of water for agricultural use in the Cariboo region. This is particularly relevant under the flow regimes projected with future climate change. As noted in Section 2, the combination of anticipated changes will act to simultaneously reduce available supply and increase demand during the agricultural production season. The primary identified issues related water storage include:

- **Water yield and water level constraints** – in some cases these constraints pertain to the available infrastructure (e.g. size of storage) and in others to competing water priorities (e.g. wildlife, recreation)
- **Changing water use/consumption** – increasing agricultural demand as well as an increase in forest fires (that compete for water supply and impact local hydrology, soil erosion, and downstream sedimentation)
- **Changing watersheds** – the effects associated with both mountain pine beetle, increased frequency and intensity of wildfire events and current forest harvesting impacting local hydrology, soil erosion, and downstream sedimentation

Table 9 summarizes these issues in more detail, and identifies some possible solutions.

Table 9: Summary of water storage issues and possible solutions

Issue	Related Concerns	Possible Solutions
Water yield & level limitations	Water yields are currently a concern for some agricultural dams	Maintain water licences and look for opportunities to **supplement existing reservoirs with additional water availability**; i.e. upstream water licences, multiple smaller storage dams/ponds within one system. Identify options to create **additional water storage**
	Water level constraints associated with other use requirements (e.g. wildlife and recreation)	Identify **common or complementary objectives with other user groups with regards to water levels**; e.g. establishing minimum draw down levels, optimizing water use while reservoir is high.
Changing water demand	Increasing agricultural demand due to hotter/drier conditions Inefficient water management practices	Explore options for **managing agricultural demand** **Upgrade irrigation systems** to minimize water loss and improve irrigation efficiency.
	Increasing and/or unpredictable water demand for firefighting - fire risk is anticipated to increase with climate change	Establish **emergency water use plans**
Changing watersheds	Changes to upstream watersheds from logging, beetle kill and agricultural activities.	Implement **local watershed planning** with all applicable stakeholders (industry, residential, agriculture). Find ways of minimizing the transfer of sub-surface water to surface water.
	Early season freshets can result in peak flows outside of agriculture production windows	Provide more **natural storage** within the upper reaches of the watershed (e.g. beaver dam development in suitable areas).

6 PRIORITY SOLUTIONS

6.1 Knowledge transfer and informational resources

Discussions with dam owners and related agencies and stakeholders have made evident that many dam owners do not have sufficient knowledge of the *B.C. Dam Safety Regulation*. Owners are not always familiar with their role and responsibilities, and the relevant agencies are only providing high level direction. Historically, some training sessions have been offered, courses are coordinated with MFLNRO and are generally offered based on interest and demand. Further written materials are provided on the website for the BC Dam Safety Program. However, there have been limited local training opportunities and there remains a knowledge gap for many of the dam owners in the Cariboo region. This reflects the need for a more cooperative approach to developing informational resources that meet the needs of Cariboo dam owners.

Local training opportunities – ideally provided through the Water Management Branch (MFLNRO), in partnership with local cattle organizations – are needed to provide dam owners with the information they require. Notifying dam owners directly about upcoming training and courses would also be valuable. Training is particularly important for owners of Significant and High Consequence dams and should include the legal implications of dam ownership (knowledge of governing regulations is necessary in the event of a failure).

Operations, Maintenance & Surveillance

Training and educational supports are also needed to assist producers with Operations, Maintenance and Surveillance. Since the majority of the agricultural dams within the region are earthfill dams less than 5 m high, this training could provide information about the *B.C. Dam Safety Regulation* and also specific maintenance and operational approaches for small earthfill dams. Examples of such training – suggested by dam owners – might include recommended methods for repairing small animal burrow holes and vegetation control practices.

Training focused on specific issues would help to ensure that information is suitably focused and serves local needs. This training could be organized by local cattle groups, possibly in partnership with the Farm and Ranch Safety and Health Association (FARSHA). FARSHA specialises in the development of training programs for farm workplaces and therefore could adapt some of their existing programs to incorporate dam safety.

Dam Safety Reviews

Although most dam owners share the same level of responsibility, owners of High Consequence dams have more requirements with respect to the completion of DSRs. In addition to finding a qualified professional to complete the DSR, owners are responsible for recording and maintaining all relevant information. If information is documented incorrectly, it could result in higher DSR costs and expensive detailed studies. Specific training for owners of High Consequence dams could help to streamline the DSR process and reduce the need for detailed studies (and associated costs).

Near-term steps

- Review previous workshop and training materials and update/refine as needed to support dam owners with addressing current regulatory requirements.
- Offer in-person (workshop) training with distinct training/knowledge transfer materials for:
    - Low and significant consequence (focused on owner responsibilities and maintenance and operational approaches for small earthfill dams)
    - High consequence dam owners (including DSR)
- Provide a summary (written) of the regulatory requirements (and potentially other information such as fact sheets on steps involved in OMS, DSRs etc.). Ensure these documents can be reviewed off line (as not all owners have internet access).
- Provide periodic refresher or supplemental educational/knowledge transfer opportunities (possibly annually for the near term)

6.2 Improving communication with dam owners

Feedback gathered during consultations and site visits indicate that there is a need for more constructive communication between the Water Management Branch personnel and dam owners. The current situation may be attributable to the shift in government approach (with more of a focus on regulation) or it may be due to frequent changes in personnel or simply lack of internal resourcing to support more extensive communication/information distribution to dam owners. Regardless of the cause, more open and frequent communication, and a more collaborative approach to addressing dam issues, would assist dam owners, and would also support more efficient implementation of dam assessments and upgrades.

Near-term steps

- Develop a collaborative approach to delivery of knowledge transfer resources (e.g. workshops and written materials) regarding the dam regulations, Operations, Maintenance and Surveillance and Dam Safety Reviews (i.e. government and sector partners working together)
- Increase the effective information flow between MFLNRO and dam owners, specifically including:
    - Inclusion of dam owners in government audits of dams
    - Provision of clear documentation for dam owners and QEPs that details how DSRs are reviewed (to aid consultants and owners in efficiently completing DSRs)
    - Provision of clear feedback to dam owners and QEPs about issues with DSRs

6.3 Finding qualified professionals

Whether they need a high level audit or a more detailed assessment of their dams, dam owners generally require the services of a qualified engineering professional. Cariboo dam owners have identified securing these services as a significant obstacle. This is in part due to the limited number of professionals with suitable expertise in earthen dam assessment, and because of the challenges with liability and lack of clarity around Dam Safety Review requirements. Some steps to assist with these challenges, and related issues identified in **Table 8**, are identified below.

Near-term steps:

- Review the list of qualified professionals produced by the Professional Engineers and Geoscientists of BC and ensure it is comprehensive (e.g. all engineers qualified to do DSRs on earthen dams are included)
- Increase awareness and distribution/availability of QEPs list
- Develop an option for dam owners to receive a top-up/cost-share on dam assessments (whether this is through a cooperative approach or assistance through an external cost-share) to assist in incentivizing engineers who may be deterred by relatively high liability/low compensation currently involved in undertaking DSRs
- Support dam owners to group together by geography and/or shared consequence rating to enable QEPs to undertake a number of DSRs at the same time (i.e. optimize time of professionals from outside the region, seek "economies of scale" by undertaking reviews as a group)

6.4 Approaches for sharing costs and risks

In addition to the identified needs around information, communication and support with assessments and OMS, a common underlying challenge for many dam owners (particularly of higher consequence dams) is the cost associated with meeting regulatory, safety and maintenance requirements associated with their dam/s. A change in the consequence rating of a dam could also substantially change the associated operation and maintenance cost.

Despite a number of past reports acknowledging the importance of agricultural dams[3] - the potential threat and cost of increased water needs associated with climate change, and the importance of dam safety – at present there is limited funding and support for either maintaining, assessing, or upgrading the dams. This challenge could potentially be addressed through a more collaborative approach that enables cost sharing and possibly also the sharing of the risks associated with dam ownership.

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[3] Documents and websites that acknowledge importance of dams to agriculture include BC Agriculture and Food Climate Action Initiative (2013 and 2014), BC Ministry of the Environment (Econnics, 2010), and online publications, such as Environment Canada (2015) and BC Ministry of Agriculture (2015).

It is important to note that a wide range of arrangements are possible – from simple one-time grants, to mechanisms for pooling resources to enable cost-savings or economies or scale, all the way through to long-term co-owner partnerships. In order to share the costs *and t*he risk, ownership of the dam (i.e. license) would likely shift to a partnership or corporate entity. This type of arrangement requires that dams owners (and their partners) be willing to partner in the ownership, control, and liability of the dam.

Three broad potential approaches along this spectrum of sharing costs and risk are outlined below, along with more detail about specific options and case studies. The broad approaches are:

- Collaboration between multiple dam owners;
- Multi-user models; and
- Granting and/or cost-sharing programs.

6.4.1 **Collaboration between multiple dam owners**

As noted above (**section 6.3**) local dam owners could group together to complete certain tasks collectively, saving on time and cost for surveillance, maintenance, and safety of their dams. This could involve a large number of dam owners working over a broader area and retaining staff, contractors, or consultants to provide the routine surveillance and maintenance, reporting, and safety assessments, such as DSR's. Alternatively this could be a smaller group and a short-term arrangement for dam owners to retain a single contractor or consultant to provide a single task (e.g. DSRs, geotechnical investigations, or spillway upgrades). Retaining services as a group could help to reduce costs through efficiencies, simplify procedures for the dam owner, and enable a more consistent and collective interface with the Dam Safety Officer.

At present a small group of local agricultural dam owners are working together with a multi-disciplinary professional team to complete a number of DSRs on High Consequence dams in the region. This approach is intended to reduce the cost of the DSR for the dam owners, as the hired professionals will find efficiencies in group studies, inspections, and discussions with the local Dam Safety Officer.

This style of collaboration could also be applied to dam upgrades when dams are similar and in close proximity. Multiple owners could hire a single designer and contractor to complete various dam upgrades to save on contracting, mobilisation, and demobilisation costs. Additionally, the use of a single contractor with suitable experience may shorten construction timelines.

6.4.2 **Multi-user models**

In addition to their use for agricultural water, agricultural dams can provide benefits to a range of stakeholders. The reservoirs store water that is often available for wildlife habitat, recreational and tourism activities, and firefighting. Water storage may also provide flood control or improve downstream fish habitat. A number of agricultural dams in the Cariboo region support shared uses or other values. Of the dams included in the consultation, 132 or 79% were reported to have other users besides the dam owner (see McLeese Lake and Jones Lake case examples). However, despite the other beneficiaries of agricultural dams, in most cases the associated risks and costs rest solely with the dam owner.

Multi-user models are suited to dam sites that have multiple values and users benefiting from the reservoir. Examples of other users include residential and recreational users, tourism businesses, provincial or federal recreation sites or parks and other agricultural producers. Mechanisms can be developed to facilitate the sharing of costs (and in some cases ownership and risk) associated with dam operation, maintenance, safety and upgrades. A small number of possible multi-user models are explored below. However, the specific circumstances of individual dams and dam owners are the main determinants in identifying the most suitable options. Key supporting criteria include:

- Dams that have other users currently benefiting from the reservoir (i.e. recreation or flood control);
- Dams with owners that are interested in collaboration;
- Accessible dams, within 2 km of highways, parks, or development may be more suitable for recreational or tourism collaboration opportunities; and
- Dams with reservoirs that overlap with existing wetland classifications or endangered / at risk species may have opportunities to seek funding from wildlife organisations or agencies that aim to help preserve wildlife habitat.

Wildlife, habitat and fisheries values and partners

Dams can contribute to a range of wildlife and habitat values particularly for fish and birds. The water stored by dams, if kept at relatively stable levels throughout the year, and from year to year, allows the development of aquatic and riparian habitats that are utilized by fish, waterfowl, other water birds and many amphibians, reptiles and mammals. Water, along with food, security cover and thermal cover, is an essential need of all fish and wildlife species, and most dams provide at least this essential need for fish and wildlife populations.

A relatively high proportion of dams may potentially have associated wildlife habitat and/or riparian values. A GIS analysis of the existing provincial data, and dams in the inventory, shows almost 60% of dams appear to have an associated wetland classification and half of the dams appear to be located within areas with species at risk or endangered species (with a 500m buffer area applied to dam location).

The inclusion of multiple stakeholders on a single dam is a concept already implemented widely by Ducks Unlimited Canada (DUC). DUC owns more dams in the Cariboo region than any other single entity and often partners with producers and landowners to act as dam owner - taking responsibility for the maintenance, inspections and upgrades - or supporting the owner. The primary objective for DUC is to conserve waterfowl breeding habitat. Partnerships between DUC and ranchers has been common throughout the Cariboo region, often in place over many years and even decades.

Although Ducks Unlimited Canada has very limited funds available for new projects, they often obtain funding for their dam rebuilds from outside sources (which also points to organizations that might partner directly with other dam owners). **Table 10** provides some possible funding sources for dam-related projects with wildlife/habitat values. In some cases, dam owners might need to enhance or strengthen values to receive funding, but these “trade-offs” may also enable critical work to occur that also achieves dam owner objectives.

Table 10: Summary of potential habitat/wildlife value partners

Funding Source	Objective	Activities Funded	Cost Covered
Habitat Conservation Trust Fund (HCTF);	To invest in projects that maintain and enhance fish and wildlife habitats that can be enjoyed by the public.	Projects that focus on freshwater fish, wildlife and habitats, with the potential for conservation, maintaining or enhancement opportunities for outdoor recreation.	No upper limit. Generally fund large projects that have another funding source.
Wildlife Habitat Canada (WHC);	Promote the conservation, restoration and enhancement of wildlife habitat. Provide a funding mechanism for wildlife habitat conservation programs in Canada. Foster coordination and leadership in the conservation community across Canada.	Projects that address priority activities under the North American Waterfowl Management Plan (NAWMP). Regional and local habitat projects of importance to migratory game birds.	Up to 20% of the total WHC funding available, 1:1 funding matching in the specified fiscal year.
National Wetland Conservation Fund (NWCF)	Support the conservation and restoration of wetlands across Canada.	The NWCF supports projects that: restore degraded or lost wetlands; enhance degraded wetlands; and, encourage stewardship and wetland appreciation by a wide variety of partners to build support for future wetland conservation and restoration activities. The NWCF focuses on working landscapes.	Will fund between \$50,000 to \$500,000.
Aboriginal Affairs and Northern Development Canada (AANDC)	AANDC fulfills an important role in developing natural resources and protecting the environment in most First Nations communities and the territories.	AANDC provides funding for programs, services and initiatives to First Nation, Inuit and Northern communities, governments and individuals as well as to Aboriginal and Métis organizations	No specified limit.
Recreational Fisheries Conservation Partnership Program	Aims to bring like-minded partners together with the common goal of enhancing the sustainability and productivity of Canada's recreational fisheries. This goal would be to restore, rebuild and rehabilitate recreational fisheries habitat.	Funds many different types of projects including, stream, lake and floodplain habitat restoration; fish access improvements; stream channel and bank erosion control and stabilization.	No specified limit.

Use of dams to maintain wildlife habitat generally places some constraints on the operation of the dam. However, quite often these constraints are minor in nature and can be compatible with agricultural water uses. For example, projects funded to provide waterfowl breeding habitat are generally required to maintain relatively constant reservoir water level during the breeding season; that is less than 150 mm fluctuation in water level typically in May to June or even mid-July. This might create the biggest limitations for sites that have large reservoirs or watersheds with sizable early summer inflow, or smaller basins with heavy irrigation withdrawal during that time period.

Earlier freshet flows expected with climate change may further challenge or reduce the availability of sites to provide waterfowl breeding. However, increased downstream flows mid to late summer may become increasing valuable for downstream fish stocks which may provide additional opportunities for funding in the future.

CASE example, Jones Lake Dam Partnership

The Jones Lake Dam is located south of 150 Mile House, off Highway 97. The dam is downstream of Jones Lake and the water control is used to back-flood the meadows surrounding the lake. The rancher that owns the land adjacent to the lake installs the stop logs during the spring, allowing water levels to rise, flooding the surrounding fields and creating waterfowl habitat for the breeding season. Once the season is complete, the land owner removes the stop logs allowing the water level to drop, providing access to fields for haying and fall grazing. **Figure 2** shows the flooded meadows adjacent to Jones Lake, with Jones Lake in the distance.

Figure 2: Looking south out at the flooded field adjacent to Jones Lake.

Near term steps

- Conduct an assessment of the types of habitats and species supported by agricultural dams including endangered species, species at risk and recreational fish habitat
- Undertake evaluations of individual dams to determine their specific habitat and/or wildlife values (for owners interested in fostering wildlife/habitat values)
- Facilitate dialogue between interested dam owners and agencies and opportunities for supportive of wildlife and habitat benefits

Recreation, tourism and/or residential values and models

The recreation, tourism and/or residential values (associated with agricultural dams) are most directly related to the reservoirs created by dams. The types of values in the include fishing, boating, camping and private and/or recreational properties around or in proximity to reservoirs.

Private land ownership around a reservoir creates the most direct way to tax for the benefits that come to residents. Local Improvement Charges (LICs) have long been used by municipalities and regional districts to help cover the costs of infrastructure improvements, such as roads and other amenities, that are deemed to benefit a specific neighbourhood or geographic area. This approach could also be used for existing developments on large reservoirs, with waterfront recreation and residential values. Such a tax could be connected to water and waterfront conservation as well as dam infrastructure operation and maintenance.

In some situations residential and tourism properties may have water licences on a reservoir. The total water authorization for residential licences on reservoir are likely to be substantially less than the licences of agricultural users which may include the dam owner. However, education around dam and reservoir stewardship could support a cooperative users association that could, in turn, help to fund dam operations and maintenance.

There are likely to be better efficiencies if a “dams maintenance service” could be implemented on a broader regional basis. A tax requisition in an electoral area or sub-region, could substantially benefit dam safety on important and high use dams in the region.

Payment for benefits associated with recreation and tourism associated with Crown lands, would be more challenging to capture. Cooperative user approaches may be more appropriate in these situations.

Case Example, McLeese Lake Dam

The McLeese Lake Dam is an example of an existing multi-user reservoir where there may be opportunity to develop cost-sharing mechanisms with other stakeholders. The dam is located on Crown land and the land surrounding the reservoir is a mix of Crown and private land with numerous waterfront residences. The dam is owned by a single agricultural producer who is responsible for the operation, maintenance, and surveillance of the dam. Boating and fishing are common on the reservoir and there are privately owned campgrounds that serve visiting tourists. Additionally, the community of McLeese Lake has developed around this reservoir and relies heavily on the lake’s presence.

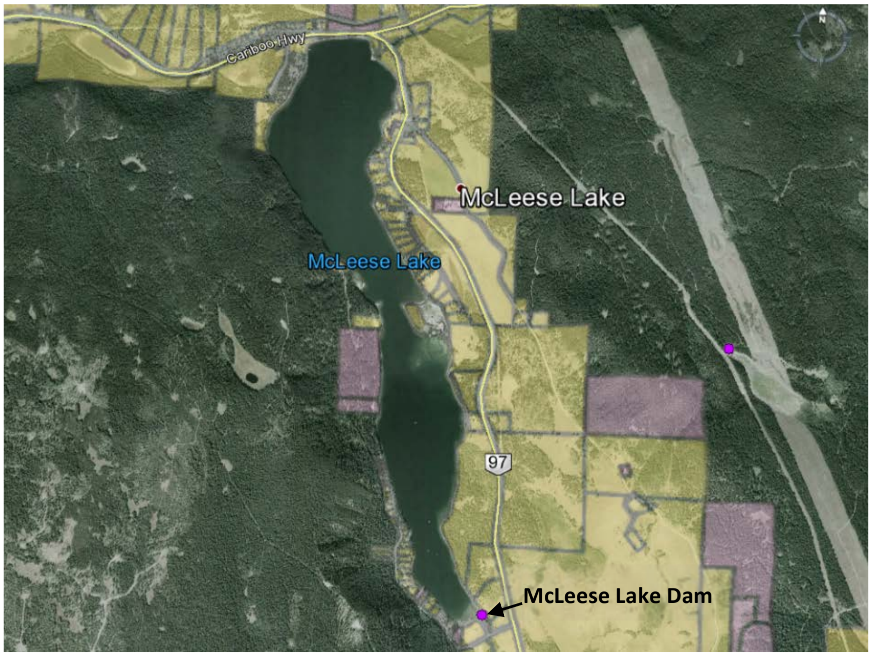

Figure 3: **GoogleEarth© image of the McLeese Lake reservoir** [*Yellow indicates private land parcels and pink indicates Crown land]*

The water stored in the reservoir is important to both the dam owner and to the community; however, the liability and responsibility rests solely with the dam owner. The McLeese Lake Dam is a High Consequence dam that is approximately 150 years old. Other beneficiaries of the dam may be willing to work with the dam owner to ensure the continued existence of the reservoir and all of its associated values.

Downstream development tax (local service area)

As new development occurs downstream of existing dams the consequence classification of dams may change; this increases the associated risks and costs for dam owners (who have no control over the development occurring). New or expanding sub-divisions that change the consequence rating of a dam could be taxed under a local service areas bylaw established under the *Community Charter* by a municipal or regional government to help share the costs for the safe operation of the dam structure. This is an existing model that could be utilized when planning new sub-divisions that are in the inundat ion area of an existing dam, or if the consequence rating of a dam is changed because of development.

Although this only provides assistance to dams in specific circumstances, it has broader provincial significance as agricultural dams across BC could be subject to increased risk and cost as the urban and residential areas downstream grow.

Near-term steps:

- Further investigate appropriate tax tools available to local government and similar application in other BC communities, including consideration of implications for implementation
- Undertake detailed case study analyses to test assumptions, levels of interest and requirements for implementation

6.4.3 Granting and cost-sharing programs

There are currently no programs in BC providing grants or cost-share assistance for agricultural dam assessments, maintenance or upgrades. However, there is potential and precedent for this type of program. Generally this would be provided as a one-time opportunity for dam owners (i.e. not applicable for multiple costs or on-going maintenance) and the level of support would likely be limited. Two specific examples are provided below for further consideration – one previous (federally-funded government) program that offered support for water supply expansion and one existing program which has an environmental risk focus and does not currently include dam related costs. These programs are only intended to provide examples of the *types* of programs that support agricultural producers with cost-share supports.

Case example 1, Environmental Farm Plan Program

The Environmental Farm Plan Program (EFP) was developed to improve environmental sustainability in the agricultural industry and provide funding to help farmers comply with sustainability-related regulations (BC Agriculture Council, 2014). The Program requires an on-farm environmental risk assessment and then offers (via the Beneficial Management Practices Program) cost-share incentives for various more in depth assessments, planning and engineering studies and/or capital infrastructure projects that have been identified to reduce environmental risk or impact. Currently, the majority of water-related beneficial management practices (BMPs) – that are cost-shared through the BMP Program – are linked to riparian management and buffers, stream crossing upgrades, erosion control measures, and irrigation management. There is little reference to water storage structures or dam safety (BC Agriculture Council, 2014).

The BMP Program has not historically included cost-share funding for BMPs related to agricultural dams. A future case could be made that the environmental benefits associated with improved water quantity and quality resulting from the implementation of agricultural dam BMPs would align with the objectives and eligibility criteria of the BMP Program. The water that is stored in agricultural dams can lead to small increases in summer base flows through seepage from the reservoir and infiltration of irrigation water. Higher base flows may improve sustainability of downstream fish habitat through increased wetted width and improved water quality (cooler temperature) if water is released from dams in a strategic fashion.

In addition, there are cost-share items within the (BMPs) Program that are closely related to the type of supports dams owners might seek, such as costs associated with technical engineering design. It is also possible that the program might extend to enable producers in relevant regions to access funding for a broader range of costs faced by agricultural dam owners; such as spillway of structure upgrades. Such changes would be beneficial to both the producers and the public by helping to supply sustainable water sources throughout the region.

Case example 2, Canada British Columbia Water Supply Expansion Program

Through this four year program (concluded in 2009) BC agricultural producers and organizations had access to technical and financial resources for planning and development of projects "to develop and enhance long-term, sustainable agricultural water supplies." Individual producers, along with a broad range of organizations (agricultural conservation, local government) were eligible for funding which was targeted at projects that (among other criteria) would help to reduce risk of future water shortages for agriculture. The Program offered funding of up to $5,000 for infrastructure projects such as "water storage systems" and larger grants were available for multi-user infrastructure projects. The approach and the focus of the program point to previous efforts to support producers with maintaining and enhancing water supply.

6.5 Redeveloping decommissioned dams

Many watercourses in the Cariboo are heavily licensed and it may be difficult to secure a new license for new storage. As an example, the Knife Creek watershed near 140 Mile, was identified by Ducks Unlimited Canada as a fully allocated system (VanSpall and Campbell, 2006). Additionally, due to the long history of dam development in the region, many of the more suitable dam locations are already utilized.

There are 35 known decommissioned or breached[4] dams in the Cariboo region. A very small number of sites were decommissioned due to shortage of water. However, based on consultation results, many other decommissioned sites were unsafe and decommissioned or breached to avoid safety concerns or the costs of maintaining and upgrading the dam. At the time of this study, the only sites that were indicated as being decommissioned due to water shortages were two Ducks Unlimited Canada sites.

Decommissioned sites may provide the most feasible opportunities for increasing future storage because they are likely to be more cost effective than new dam locations. During consultation, dam owners of decommissioned dams expressed interest in having their dams redeveloped, further suggesting opportunities for sustaining or increasing future water availability.

[4] The definition of a decommissioned or breached dam may vary between agencies or groups. However, no clear distinction has been consistently used. Therefore, for the purpose of the study dams classified as either decommissioned or breached have been considered similar.

Near term steps

- Undertake a more detailed study of the decommissioned and breached dams to identify those that are of highest priority for future development – include water storage potential, local area water demand, benefits to other resources and high level estimates of upgrade costs in analysis

Case Example, Sword Creek Decommissioned Dams

The Sword Creek system is composed of two active and three decommissioned dams. The two remaining active dams are the most downstream on the system. Sword Creek Reservoir #2, one of the decommissioned dams, is located just upstream of Meldrum Creek Road on the Sword Creek system.

The site consists of an earth dam that has a failed outlet structure which resulted in its decommission and the draining of its reservoir. During the site visit – completed in early spring – water was present in the bottom of the reservoir. The owner indicated that this system runs throughout the majority of the year. The owner also suggested that if the site was to be rebuilt, that the dam capacity could be increased to provide additional storage beyond what was historically available at this site. Rebuilding this dam could provide the owner with an additional 222,000 m^3 (180 acre feet) of water storage.

Redevelopment of this site would require an engineered design, structural earth fill, and a new outlet structure and spillway. The costs associated with the design and reconstruction of this project are estimated to be in the range of $ 300,000 to $ 400,000, assuming use of local materials for embankment fill. Cost may be reduced if equipment, operators, and labour are supplied by the dam owner.

This particular site was previously considered for redevelopment approximately 10 years ago. The owner applied for funding through the Prairie Farm Rehabilitation Administration (PFRA) and although application was accepted, the program ran out of funding before the project was executed.

Figure 4: Decommissioned Sword Creek Reservoir #2 dam, view looking west with flow from right to left.

Figure 5: Failure at the outlet structure on the decommissioned Sword Creek Reservoir #2 dam.

6.6 Managing agricultural water demand

Based on consultation with producers and relevant agencies, most irrigation users have systems in place to manage water use. However, these systems are not always efficient with respect to water losses. Older irrigation systems generally have leaks and open ditch systems can result in overuse along with losses through evaporation and infiltration to groundwater.

Upgrades to irrigation systems can help to preserve water for use later in the season. Necessary upgrades will vary depending on the existing system. Producers with systems in need of upgrades can access cost-share funding for the development of a Certified Irrigation Management Plan through the Beneficial Management Practices Program. The Program currently provides relatively high level cost-shares for agricultural operations in the interior of BC to assess and upgrade their irrigation systems.

Regardless of irrigation system and management practices, climate change is likely to increase irrigation demand as longer hot and dry periods occur. This will put stress on agricultural water storage and expansion of storage may still be required. There may be other suitable adaptations that can enable producers to reduce water demand. For example, the use of more drought tolerant or water-efficient crop varieties, and the adoption of production practices like Management-intensive grazing (MiG) that enable a reduction in water requirements or use, or support increased water retention in soils.

Near-term steps

- Conduct outreach regarding availability of irrigation management planning and cost-shares on irrigation infrastructure improvement through EFP Program (e.g. written materials, workshops or speakers at local agricultural events/meetings)
- Continue to initiate and support local research and knowledge transfer for improved resilience to drier conditions (e.g. MIG research, forage variety trials etc.)

6.7 Watershed planning & natural water storage enhancement

Watershed planning is an important step to proactively address future water supply in areas with water yield concerns. This planning will necessarily to involve multiple stakeholders and is likely to be highly complex but can support cooperative actions to stabilize and/or enhance supply. For example, enhancing storage within upstream watersheds can help to reduce variability of the smaller events and increase or extend summer base flows. Since water storage is affected by the activities occurring within a watershed, improving awareness of these interrelationships and exploring options for reducing negative impacts requires a collective planning process and commitment. Beaver activity, logging, and agriculture can all have an impact on the available water within a given watershed. Watershed planning could support a more holistic approach to managing the Cariboo region's water resources and ensuring water storage is sufficient for agriculture and other critical uses.

Logging Practices

Logging activities can alter the natural hydrology of a watershed through both changes in forest cover, resulting in more rainfall being converted to runoff, and by intercepting groundwater flows. During road construction, ditches intercept and convey groundwater to natural low points that are often channels or creeks. This increases the drainage efficiency and can lead to higher flows during the freshet and storms while reducing upland storage and late summer base flows (Elizabeth Myers Toman, 2004). Methods to restore subsurface flows can be incorporated into forest road construction practices; such as promoting infiltration within water conveyance infrastructure.

Multiple Storage Systems

Large dams are costly to develop and to maintain, and large storage areas are not always available within a watershed. It may be possible to increase storage within low-gradient watersheds through the development of a series of smaller dams, limiting the risk and costs associated with larger structures. However, for this to be a viable solution – agricultural producers and other individuals and groups will need to work together to determine suitable approaches to new infrastructure.

The construction of small dams and reservoirs that are connected within a watershed can help to maintain water storage throughout dry portions of the year. These types of systems are both beneficial to agricultural operations and wildlife.

Beaver Activity

In suitable areas beaver activity may encouraged to increase natural storage within a watershed. Beavers provide natural storage by constructing small dams and creating wetland habitat. Depending on the location of the beaver activity, beaver dams can be both beneficial and detrimental to farming activities. While there are techniques available to work around this problem, beavers have been known to plug dam spillways and outlet structures, road culverts and flood farm land. However, if beaver dams are constructed upstream of storage reservoirs or farm land they can provide natural storage within creeks and channels that will help to slow down runoff and freshet flows.

Case Study, DUC Borland Creek Complex

The Ducks Unlimited Canada 148 Mile Marshes project, located near 150 Mile House along Borland Creek, is a good example of this type of system. The project has 26 small dams which are used to store water for stock watering and waterfowl habitat, allowing water to seep into the groundwater system and be released into downstream systems throughout the season. Because there are many small dams, rather than one large one, the risk posed by the water storage is smaller and therefore the consequence rating is minimized. Additionally smaller water controls are required on each one which further minimizes cost of initial construction. **Figure 6** is an example of one of the small dams that is part of the Borland Creek system.

Figure 6: Looking upstream (north) towards one of the small DUC dams within the Borland Creek system.

Near-term steps

- Identify areas in need of near-term watershed planning support
- Identify key partners with shared interest in undertaking a planning process
- Seek funding support/partnerships to initiate watershed planning

7 CONCLUSIONS

The agricultural dams of the Cariboo region provide water storage which will become increasingly critical to the sector's viability as climate change affects hydrology and more extended hot and dry periods become more frequent. While agricultural water – both for irrigation and livestock water – is the primary purpose of most of the dams in the Cariboo, many of them also support other values such as wildlife habitat and recreation and tourism activities. Outlining options for sharing the risks and costs associated with maintaining agricultural dams was one of the main objectives of this report. The offered solutions are intended to stimulate further discussion and, along with additional options and opportunities that may emerge, to assist in finding effective and efficient options to maintain and improve dam infrastructure.

The challenges with maintaining and enhancing agricultural water storage in the region are complex and near-term solutions are needed for the most immediate and pressing problems – largely the requirements and costs associated with dam safety. Some immediate steps can be taken to improve knowledge transfer and clarity around processes and requirements for dam safety. It is hoped that this report assists with these actions, but also encourages broader consideration of the longer-term value of safe and sustainable water storage infrastructure into the future.

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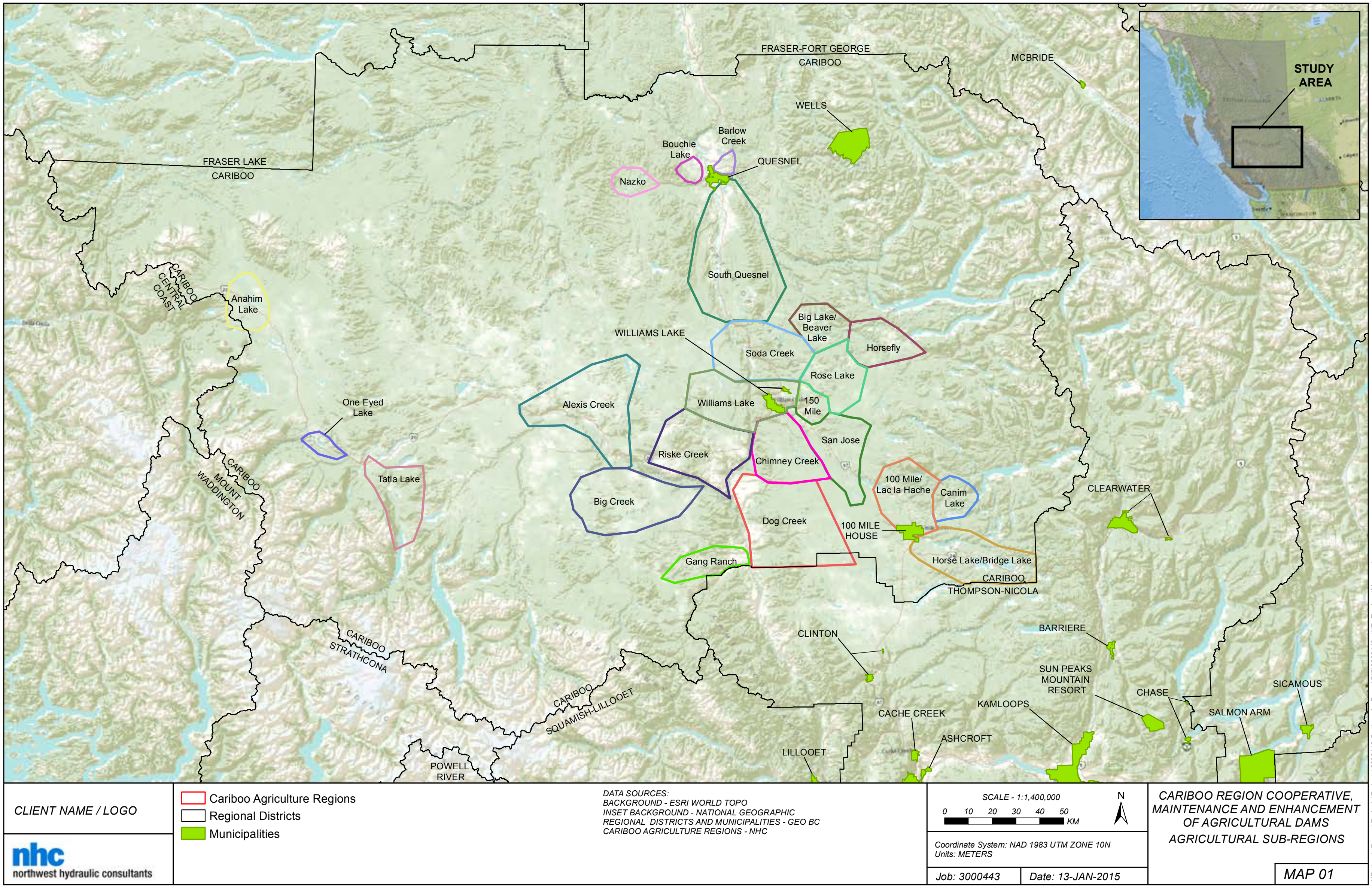
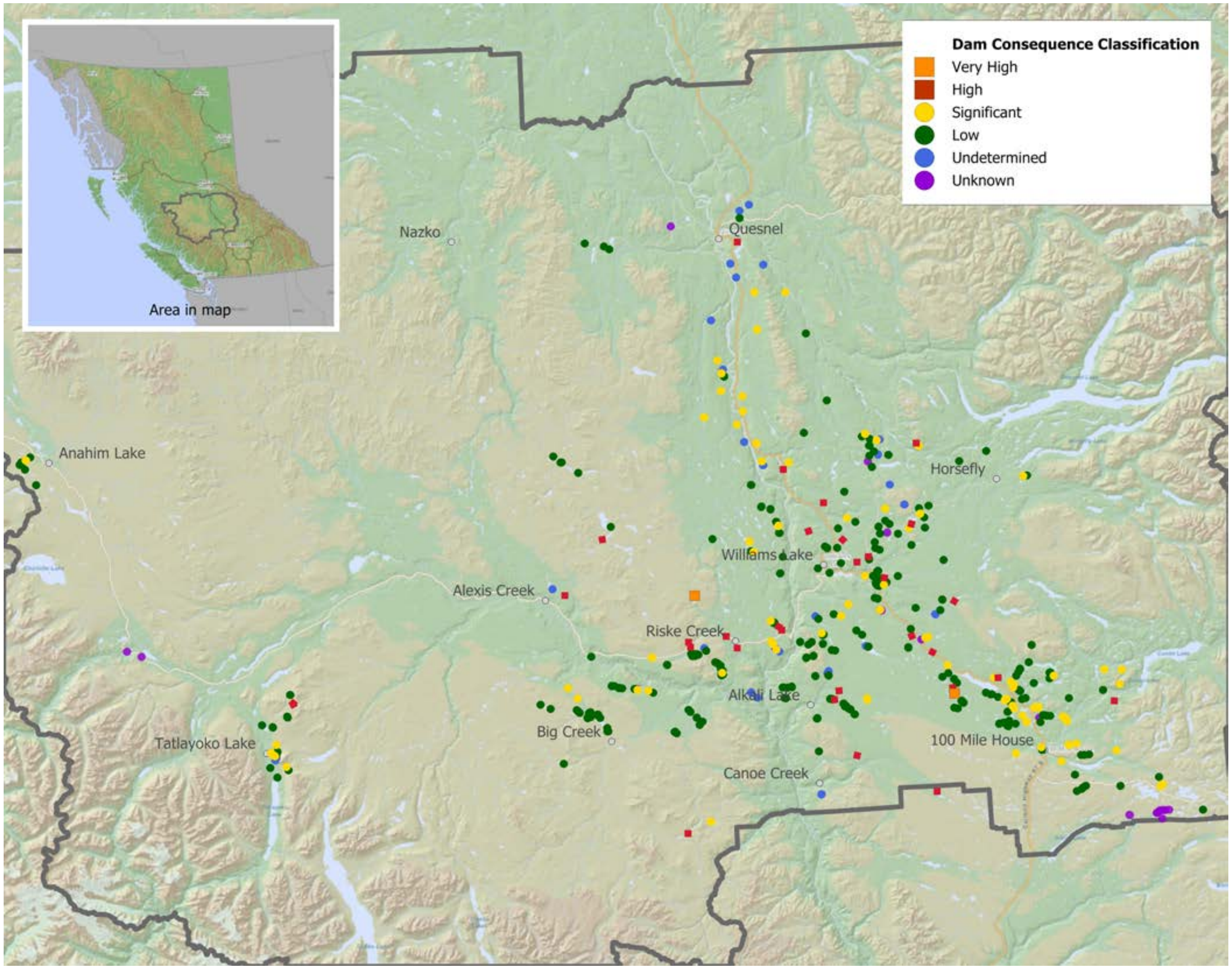
APPENDIX A

Project Maps


FRASER-FORT GEORGE
CARIBOO
MCBRIDE
STUDY AREA
WELLS
Barlow Creek
Bouchie Lake
QUESNEL
Nazko
FRASER LAKE
CARIBOO
CARIBOO CENTRAL COAST
Anahim Lake
South Quesnel
Big Lake/ Beaver Lake
Horsefly
WILLIAMS LAKE
Soda Creek
Rose Lake
Alexis Creek
Williams Lake
150 Mile
One Eyed Lake
San Jose
Riske Creek
Chimney Creek
CARIBOO MOUNT WADDINGTON
Tatla Lake
100 Mile/ Lac la Hache
Canim Lake
Big Creek
CLEARWATER
Dog Creek
100 MILE HOUSE
Gang Ranch
Horse Lake/Bridge Lake
CARIBOO
THOMPSON-NICOLA
BARRIERE
CARIBOO STRATHCONA
CLINTON
SUN PEAKS MOUNTAIN RESORT
CARIBOO SQUAMISH-LILLOOET
CHASE
SICAMOUS
KAMLOOPS
CACHE CREEK
SALMON ARM
ASHCROFT
LILLOOET
POWELL RIVER
CLIENT NAME / LOGO
nhc
northwest hydraulic consultants
Cariboo Agriculture Regions
Regional Districts
Municipalities
DATA SOURCES:
BACKGROUND - ESRI WORLD TOPO
INSET BACKGROUND - NATIONAL GEOGRAPHIC
REGIONAL DISTRICTS AND MUNICIPALITIES - GEO BC
CARIBOO AGRICULTURE REGIONS - NHC
SCALE - 1:1,400,000
0 10 20 30 40 50 KM
N
Coordinate System: NAD 1983 UTM ZONE 10N
Units: METERS
Job: 3000443
Date: 13-JAN-2015
CARIBOO REGION COOPERATIVE, MAINTENANCE AND ENHANCEMENT OF AGRICULTURAL DAMS
AGRICULTURAL SUB-REGIONS
MAP 01

MAP 02: Map showing location and consequence ratings of Cariboo region dams included in the study inventory



APPENDIX B

Consultation Guidance Document

northwest hydraulic consultants

Cariboo Region Cooperative Maintenance and Enhancement of Agricultural Dams
Consultation Frame Work - Talking Points

Dam Owner:
Dam Name(s):
Consequence Rating:

Consultation Completed by:
Date of Consultation:
Type of Consultation: Phone Call/In Person

Consultation Talking Points		Comments
Dam ownership	Water licences (multiple, single)	
	Active water users	
	Other sector beneficiaries such as recreation, tourism, wildlife	
Water usage	What is it used for?	
	Sufficiency or yield problems?	
	Any recent changes? (e.g. higher freshet flows and less flow later in the season and limited stock watering capacity in winter, etc.).	
Future water storage opportunities	Any local opportunities within the catchment	
	Opportunity to use another existing dam	
	Different water licence?	
Status of the dam	Confirm size of dam and how it works	
	Who conducts the required the weekly surveillance (including dam inspections conducted by the owner), day to day operations, and maintenance of the dam(s)	
	Is there any possibility of you needing to decommission the Dam?	
DSR	Has a Dam Safety Review been completed? Associated findings (i.e. were any deficiencies or non-compliances with the dam safety regulation found; what are the recommended courses of action	
	Costs associated with the above-mentioned dam management activities	
	Any government audits?	
OMS	Is there an OMS plan? If yes, is it followed?	
	Costs associated with dam OMS that are facing the owners	
Agencies	Experience with DSO (Positive/negative)	
	Any experience with Water Management branch personnel other than local DSO?	
Collaborative approaches/models to sharing of costs and risk	Multiple producers coming together for a single or collection of dams	
	Other stakeholders sharing the costs (i.e. Ducks Unlimited, local First Nations, tourism or municipal, regional, provincial, or federal government),	
	Obtaining resources for dam maintenance and upgrades from corporations looking to mitigate for wetland loss	
	Do you see any benefit to reducing costs by using a single entity to administer dam inspections, and/or maintenance for dams within the region, sub-region, or watershed?	
Owners Input	Any other leads that will help our investigation.	

APPENDIX C

Detailed Climate Change Findings

CLIMATE CHANGE & THE SAFETY OF SMALL DAMS IN THE CARIBOO REGION

Introduction: Current State of Knowledge

Future changes in the hydrological regime of the small watersheds upstream from agricultural dams in the Cariboo Regional District, stemming from regional warming anticipated as a result of anthropogenic climate change, may carry consequences for dam safety. The current understanding of foreseeable effects is summarized in Figure Some foreseeable hydrological changes result directly from future warming – as is the case of a partial shift from snowfall to rainfall in the cold season, the earlier arrival of the snowmelt hydrograph, and further loss of glacier cover. Others result indirectly from future warming, stemming from the increased vulnerability of the region's forest cover to mountain pine beetle infestation (which has already taken an enormous toll on the region, given the loss of the controlling effects of very cold spells), and from increased incidence of wildfires.

The arrival of peak inflows earlier in the season, at a time of year with increased likelihood of experiencing a rainstorm (rather than snowstorm), indicates a likelihood of higher runoff peaks. Rising temperatures may also lead to very rapid snowmelt and high runoff peaks. The B.C River Forecast Centre (RFC, 2012) informs that: *"The critical weather factors that result in increased risk of flooding are extended periods of hot weather, or a significant frontal rainstorm near the time of peak snowmelt."*

Loss of tree cover and soil changes associated with beetle infestation and salvage logging can contribute to higher runoff peaks. The following factors were listed by Alila (2007): increased accumulation of snow in grey and salvaged logged stands compared to green stands, reduction of shading in grey stands and no shading in salvage logged stands, and increased wind speed at the snowpack surface in salvaged logged stands, which can accelerate snowmelt. Wildfires can also have some of these effects.

Thus, dam safety needs are for a) higher spillway capacity, and b) a larger flood control reservation, i.e., a reservoir volume not made available for storage but reserved to accommodate a large incoming flood volume. Such a limit on water storage is problematic, however, when agricultural needs in summer are for larger storage volumes. Warming is indeed expected to result in growing water deficits in summer, due to the combined effects of earlier snowmelt, diminished infiltration, higher potential evapotranspiration, and further retreat of glacier cover (the source of summer streamflows in some watersheds, such as the Quesnel). The increased supply of sediment also has implications for reservoir storage capacity and the lifetime of the dam.

Given the foreseeable effects of climate change we can thus anticipate conflicting future needs (**Figure 1**). Dam safety concerns, in the face of rising peak inflows, are for growing flood control reservations in reservoirs; while drier, hotter, and longer summers lead to agricultural needs for growing water storages in reservoirs. If the anticipated increase in erosion rates results in increased sedimentation of reservoirs, this will contribute to reduced storage capacity. The *Cariboo Adaptation Strategy* document of British

Columbia's Climate Action Initiative[1] (BCCAI, 2014), anticipates many of these conflicting needs. The document concludes that: *"Enhancing water storage capacity is one means of reducing vulnerability associated with extended dry periods and warmer temperatures. Water quantity and storage have been identified as a significant issue in broader watershed initiatives within the region (27)."* (BCCAI, 2014: page 16). But it also concludes that: *"With climate change, the conditions that cause flooding, runoff and associated erosion are anticipated to increase in frequency and intensity."* (BCCAI, 2014: page 15)

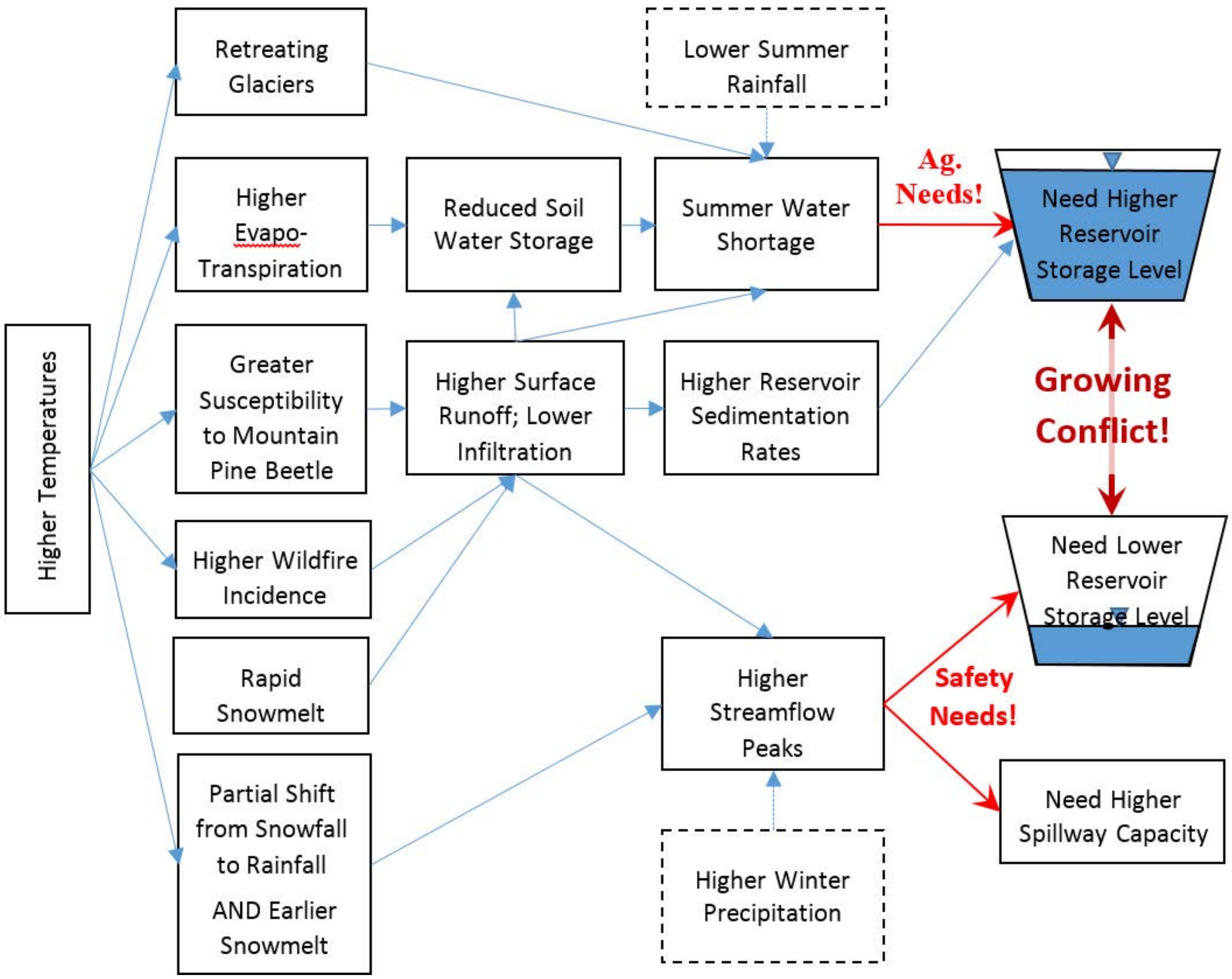


Figure 1. Potential consequences of climate change for agricultural dams in the Cariboo region.

Dashed boxes represent future precipitation trends indicated by several, but not all, Global Climate Models..

Over the 20th Century, the southern half of British Columbia has seen a trend towards warmer and wetter conditions, with diminished snowpack and glaciers – conditions that resulted in greater streamflow variability from year to year (Déry et al., 2012). Mean annual air temperature has risen by

[1] http://www.bcagclimateaction.ca

about 1°C during 1895-1995, and the warming in winter and spring in the southern interior British Columbia regions has surpassed 1°C; while precipitation increased by 2-4% per decade in 1929-1995 (Fraser and Smith, 2002). As for many northern regions, B.C.'s 20th Century warming was greater than the global average, estimated at 0.6°C (IPCC, 2007; 2014).

The increase in the daily minimum temperature has been even faster (e.g., Rodenhuis et al., 2007). Burford et al. (2009) analyzed the daily temperature record at Quesnel for 1926-2003, and identified a rise in the annual-averaged daily minimum temperature by 1.4°C (for the winter period, this value was 3.5°C) and a rise in the annual minimum temperature (the lowest value registered each year) by 5.2°C over that period. The maximum daily temperature had a rising trend in Winter (by 1.3°C in the study period). However, the annual maximum temperature (the highest value registered each year) was found to have a declining trend instead, with a -0.9°C change in 1926-2003. No significant trend was identified in mean annual temperature. Burford et al. suggested that an increasing minimum and declining maximum might be explained by increasing cloud cover in a more moist atmosphere.

Very cold winter spells control mountain pine beetle populations, hence rising minimum annual temperatures increase forest susceptibility to beetle infestation. Tree die-off and salvage harvesting, by reducing forest cover and sometimes also due to road construction associated with salvage harvesting, have been shown to contribute to increases in peak runoff, soil erosion, and landslide risk (e.g., Carver et al., 2009; Weiler et al., 2009; Schnorbus et al., 2010; Schnorbus, 2010). It may also decrease the soil's water retention capacity and recharge rates. Warming and summer drought also increase forest susceptibility to wildfires, which, due to loss of forest cover and changes in soil properties, can lead to increases in peak runoff, soil erosion, landslide risk, and lower recharge rates for soil water. Wildfires may also decrease the soil's water retention capacity and recharge rates.

Glacier melt is the source of summer streamflows in some Cariboo watersheds, such as the Quesnel (e.g., Burford et al., 2009). Stahl and Moore (2006) analyzed August streamflows in British Columbia, finding significant and widespread decreasing trends for glacierized catchments, but not for catchments without glaciers. These authors explain the effects of retreating glaciers on summer streamflows. There is a first phase where summer streamflow increases, *"due to the earlier disappearance of high-albedo snow and the exposure of lower-albedo firn and/or ice, as well as the effects of increased energy inputs [Singh and Kumar, 1997]."* Later, in a second phase, *"glacier recession may decrease glacier area sufficiently to reduce meltwater volumes, generating concerns about the future sustainability of summer flows [Barnett et al., 2005]."* Thus, Stahl and Moore suggest that British Columbia glaciers have already reached their second phase.

The Pacific Climate Impacts Consortium (PCIC)[2] is a regional climate service centre at the University of Victoria, and has played an important role in supporting the *Cariboo Adaptation Strategy* of British Columbia's Climate Action Initiative[3] (BCCAI, 2014), for which it has provided agriculturally relevant regional climate projections. One of PCIC's key contributions was to apply a state of the art hydrologic

[2] http://www.pacificclimate.org

[3] http://www.bcagclimateaction.ca

model (the Variable Infiltration Capacity model, VIC) to simulate the hydrologic response of individual watersheds to the future temperature and precipitation conditions simulated by several global climate models (GCMs) under different future scenarios of global greenhouse gas emissions. VIC was applied at a spatial scale of 1/16°, i.e., at individual grid cells of about 38 km^2 [producing simulated runoff for every grid cell at daily time resolution. VIC simulates the water and the full energy balance over each grid cell – important in a cold, snow-dominated region such as the Cariboo.

PCIC's application of VIC to the Fraser River basin, and the results of the VIC runs for eight different GCMs and three greenhouse gas scenarios are described in the journal article Shrestha et al. (2012). These climatic and hydrological projections also served as a basis for the Cariboo Adaptation Strategy document (BCCAI, 2014: pages 5-7), and their foreseeable agricultural impacts were explored (BCCAI, 2014: pages 8-10). The GCM runs used in these VIC runs are those associated with the Fourth Assessment Report of the U.N. Intergovernmental Panel for Climate Change (IPCC, 2007). Although more recent GCM runs are available, associated with the Fifth Assessment Report (IPCC, 2014) no corresponding VIC runs have as yet been produced.

The article by Shrestha et al. (2012) analyzes these hydrologic projections for larger watersheds, i.e., larger than those that lie upstream of agricultural dams. Below, we will analyze the projections for individual hydrologic model grid cells at the locations of three representative agricultural dams. The grid cell results are used as indicative of the response of the small watershed upstream of the dam.

Analysis of the 8 GCM projections for these three locations leads to the following general findings, consistent with the state of knowledge summarized above. The projected future rise in the mean annual temperature by the end of this century ranges between about 3°C and 6°C, depending on the GCM and specific spatial location. The projected future changes in precipitation vary with the GCM as well, and vary somewhat over the region, but several GCMs project increases in fall and winter and decreases in summer precipitation. The temperature rise leads to a partial transition from snowfall to rainfall in winter and spring, and also leads to earlier snowmelt. The peak snowmelt period is projected by all GCMs to move progressively throughout this century from its historical timing of April-May, to March-April by end of this century. The likelihood of rainfall occurring during the snowmelt period thus increases considerably, and can lead to pronounced runoff peaks.

Analysis of Hydrologic Projections for Three Representative Dam Locations

Here we use the VIC simulations reported in Shrestha et al. (2012), and analyze the hydrological changes projected for individual model grid cells. We choose grid cells at the locations of three high-consequence agricultural dams, taken to be representative of other dams as well. The three locations chosen are McGhee Lake dam, Dragon Lake dam, and Chris Lake dam – indicated on the map in **Figure 2**.

We emphasize that measured streamflows available for model calibration were not available for small watersheds, only relatively large ones (Shrestha et al., 2012), therefore hydrologic projections for individual grid cells may be unrealistic. The hydrologic projections analyzed in this work should, therefore, be considered plausible representations of the future, given the best current scientific information, and do not represent specific predictions. Projections that concern extreme climatic or streamflow events have even higher associated uncertainty than projections of seasonal means.

We analyzed the results from all eight GCMs used by the PCIC for the three representative locations, for the A2 scenario of greenhouse gas emissions. The A2 scenario was chosen (rather than A1B or B1) because it assumes the highest greenhouse gas emissions toward the end of this century. Since the time these scenarios were developed, in the 1990s, estimated actual emissions have surpassed those assumed of the A2 scenario, hence this scenario cannot be considered unrealistic.

Despite wide differences in mean annual runoff at the three representative locations, the hydrologic projections for the three were qualitatively similar. For this reason, and to avoid an excessive number of figures, in this section we present for the three locations the results of just one GCM: the Canadian CGCM3-1 (**Figure 3 and Figure 4**).

In **Figure 3**, we can appreciate the differences between the monthly mean values of temperature, rainfall and snowmelt for the three locations. Rainfall and snowmelt are plotted rather than total precipitation, because they are the sources of liquid water to the region. The historical values (simulated for 1955-2009) are represented by the blue line in each figure panel. The most significant differences between the three locations pertain to snowmelt, which attains a much higher maximum monthly total at Chris Lake. Significantly earlier arrival of the snowmelt peak (at the monthly scale) is not seen until mid-century (2040-2069) for McGhee Lake and Dragon Lake, and not until the late-century (2970-2098) for Chris Lake.

As a response to snowmelt, soil water storage rises over time, reaching a maximum in April-May for historical conditions (soil moisture blue line for 1955-2009 in **Figure 3**), but by the end of this century this maximum will be reached earlier, in March-April. Because runoff in this region is dominated by baseflow, runoff responds directly to the rise in soil water storage, and has a very similar timing, as seen in **Figure 3**.

To explore the implications for peak daily runoff, we display in **Figure 4** the statistical distribution of daily runoff over each time horizon. All days of the year are included in each distribution plotted. The shift over time of the distribution to the right, i.e., towards higher values, is evident for all three locations. A statistical test can be performed to determine the statistical significance of these differences.

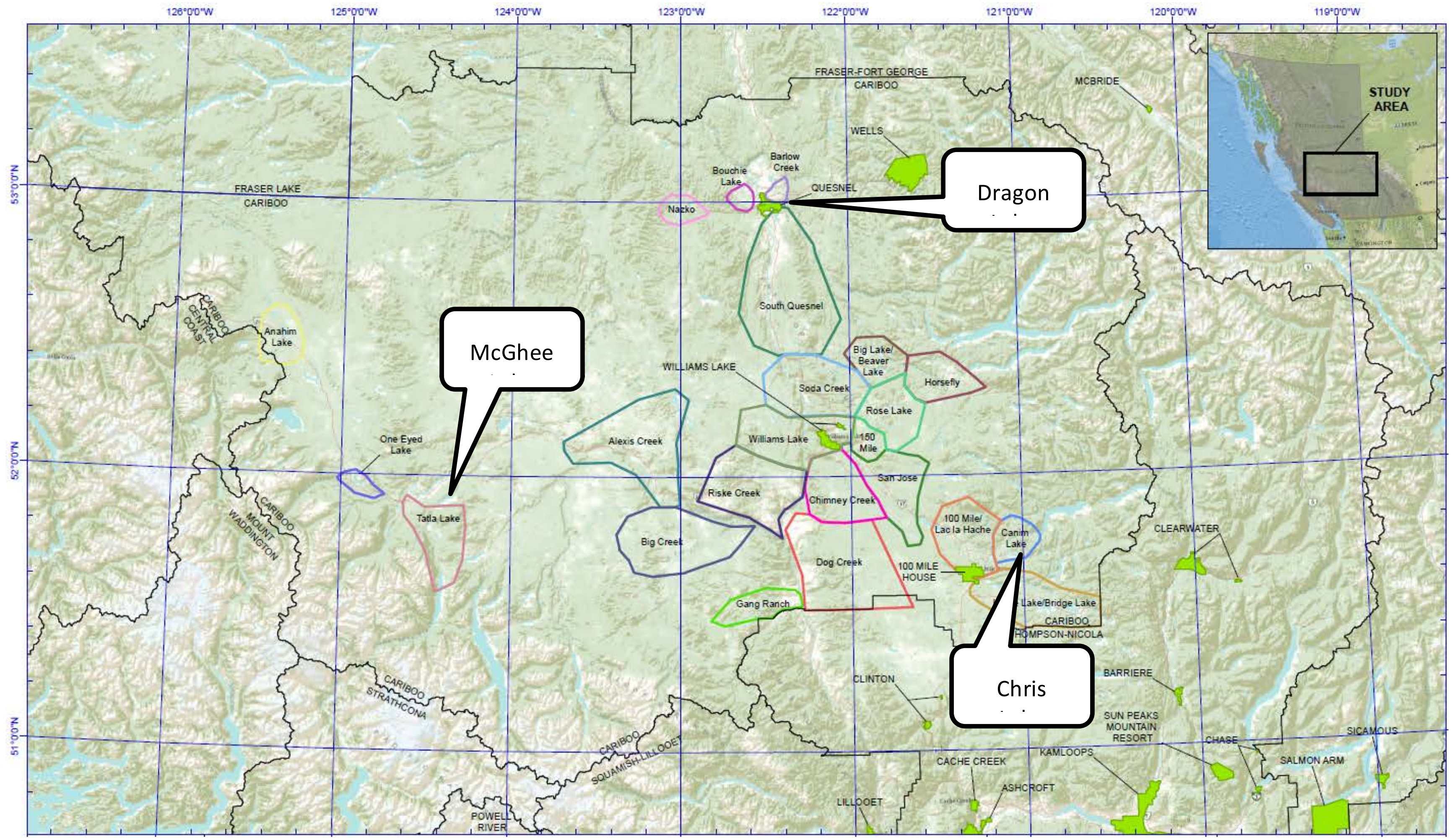
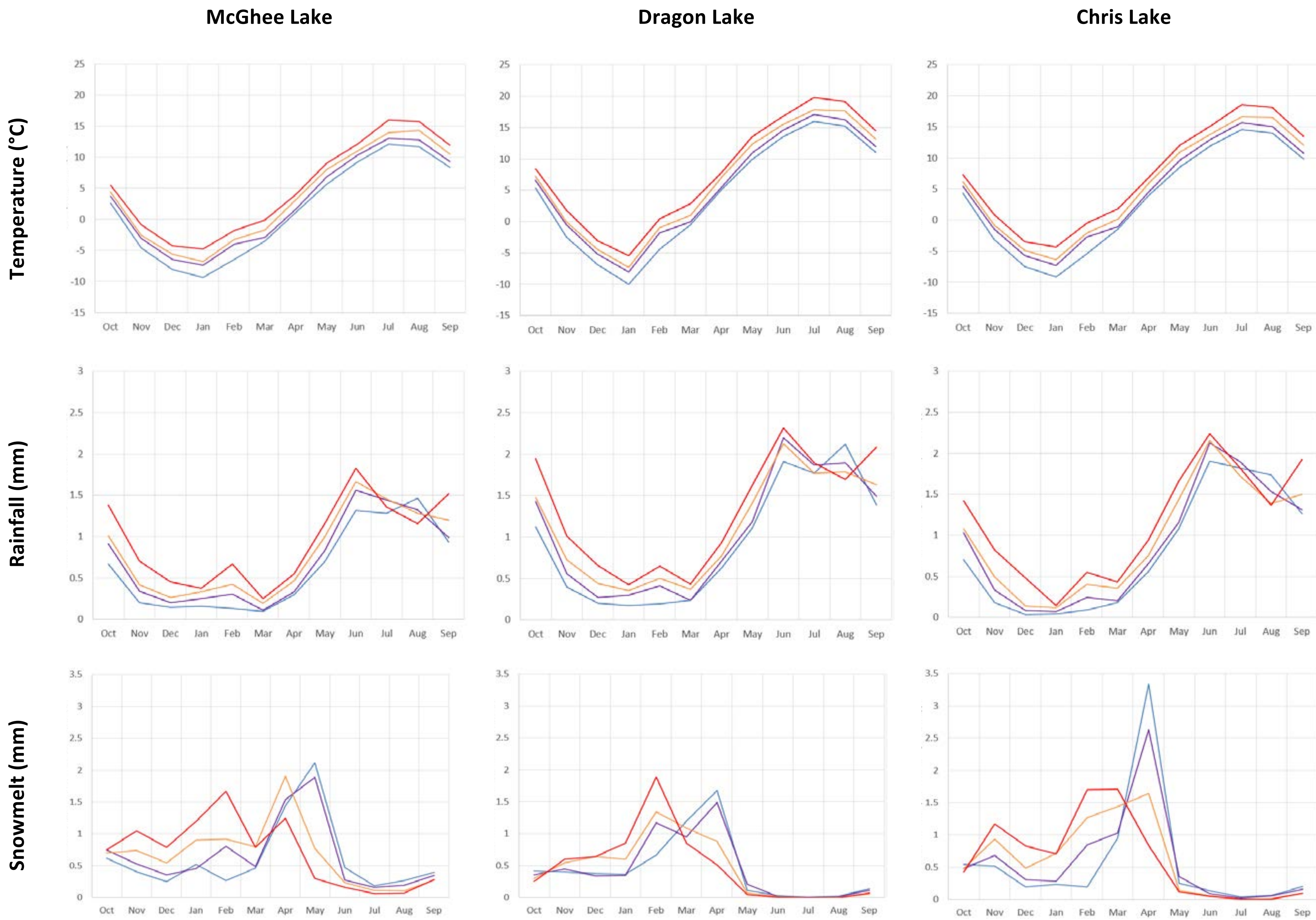


Figure 2. Three representative locations of high-consequence agricultural dams: McGhee Lake, Dragon Lake, and Chris Lake.


McGhee Lake
Dragon Lake
Chris Lake
Temperature (°C)
Rainfall (mm)
Snowmelt (mm)
25
20
15
10
5
0
-5
-10
-15
3
2.5
2
1.5
1
0.5
0
3.5
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

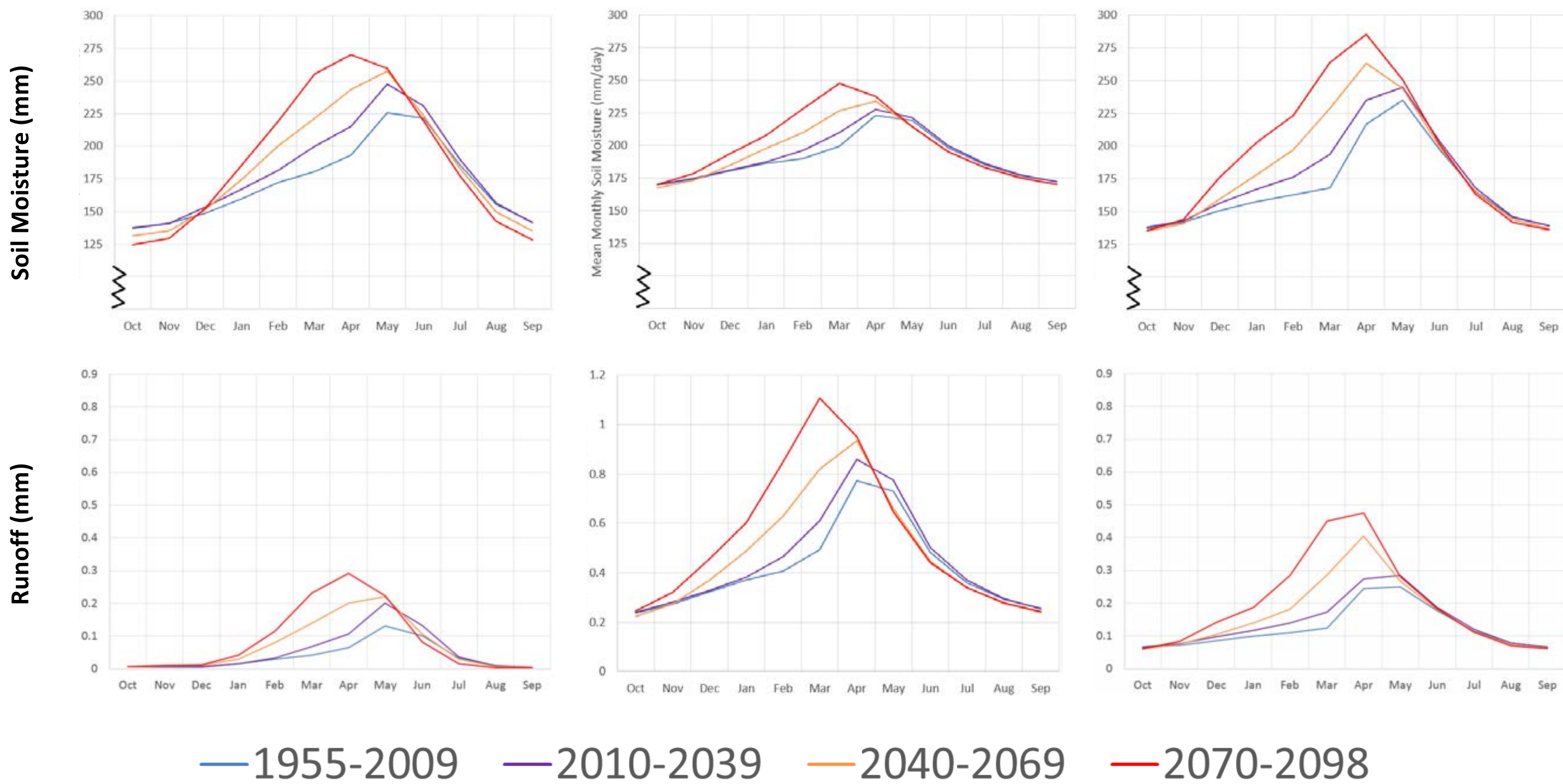


Figure 3. Summary of mean monthly projections by CGCM3-1 (A2) for the representative locations, for three future time horizons. (This figure spans two pages.)

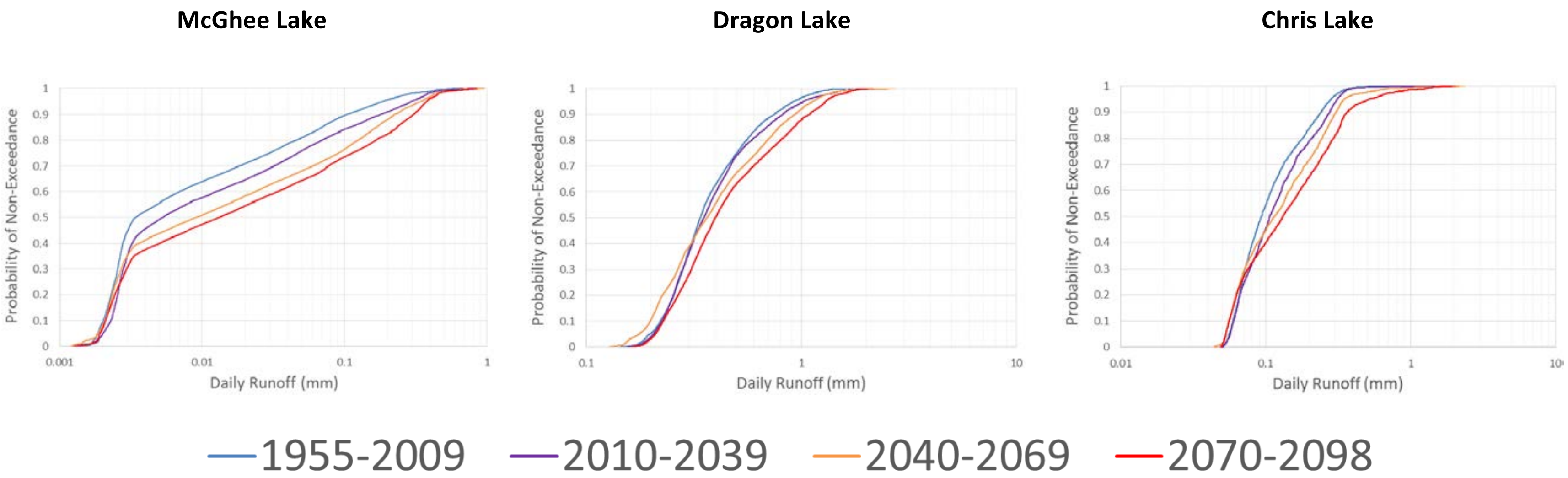


Figure 4. Cumulative Distribution Function of daily runoff for the three representative locations, for different future time horizons.

Uncertainty Associated with the Results Presented

While there is a need to provide quantitative information for water resources planning and flood protection planning, the underlying projections of climate change are subject to large and unquantifiable uncertainty. The main sources of uncertainty are unknown future emissions of greenhouse gases, uncertain response of the global climate system to increases in greenhouse gas concentrations, and incomplete understanding of regional manifestations that will result from global changes (e.g., Hawkins and Sutton, 2010).

The downscaling, in space and time, of GCM-projected climate variables, and the application of the hydrologic model represent additional sources of uncertainty. Measured streamflows available for model calibration were not available for small watersheds, only larger ones, therefore hydrologic projections for individual grid cells may be unrealistic. The hydrologic projections analyzed in this work should, therefore, be considered plausible representations of the future, given the best current scientific information, and do not represent specific predictions. Projections that concern extreme climatic or streamflow events have even higher associated uncertainty than seasonal means.

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Appendix D

Sample Canadian Dam Association Guidelines

CANADIAN DAM ASSOCIATION - DAM SAFETY GUIDELINES

The Canadian Dam Association (CDA) is composed of a collection of dam owners, operators, regulators, consultants and suppliers from across Canada with experience and an interest in dam safety. The CDA's primary objectives revolve around responsible and safe management of dams, and improving the knowledge and awareness of dams (Canadian Dam Association, 2015).

The CDA has produced Dam Safety Guidelines (2007) that are generally accepted for providing the expectation for many of the activities required under the Regulations. As an example the CDA Dam Safety Guidelines provides recommendations for hydrotechnical and seismic design requirements, which are to reviewed during DSRs or other detailed studies.

Hydrotechnical Considerations

The design flood that a dam can withstand without failure is classified as the Inflow Design Flood (IDF). This design requirement varies depending on the downstream consequence classification associated with the individual dam. **Table 12** outlines the CDA's recommendations for IDFs of varying dam classifications.

Table 1: CDA hydrotechnical recommendations for IDFs (Canadian Dam Association, 2007).

Consequence Classification	Inflow Design Flood Requirements
Low	1 in 100 year
Significant	Between a 1 in 100 year and 1 in 1000 year
High	1/3 between the 1 in 1000 year and Probable Maximum Flood (PMF)[1]
Very High	2/3 between the 1 in 1000 year and Probable Maximum Flood (PMF)[1]
Extreme	Probable Maximum Flood (PMF)[1]

Note 1: The PMF has no specified annual exceedance probability.

Seismic Hazard Considerations

The CDA's seismic recommendations reflect the geotechnical considerations with regards to annual exceedance probability (AEP) of a given design earthquake. Varying earthquake design ground motions (EDGM) are recommended at the location of the dam, as outlined in **Table 13**. The earthquake loadings are to be established from the appropriate design criteria, reflecting the level of safety required for the individual dam.

Table 2: CDA suggested design earthquake levels (Canadian Dam Association, 2007).

Consequence Classification	Annual Exceedance Probability for Earthquake Design Ground Motions
Low	1 in 500 year
Significant	1 in 1000 year
High	1 in 2500 year
Very High	1 in 5000 year[1]
Extreme	1 in 10,000 year[1]

Note 1: The EDGM value must demonstrate conformance to societal norms of acceptable risk. Justification can be provided with the help of failure modes analysis focused on the particular modes that can contribute to failure initiated by a seismic event. If justification cannot be provided, the EDGM should be the 1 in 10,000 year event.